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Proposed Set of PMDs, Related Specifications and Rationale

Presented By

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Objective

- To propose a set of PMD implementations that
  - meet all the P802.3ae distance objectives and criteria
  - provide an optimal mix of technologies
- The set consists of
  - Serial 850 nm
  - 850 nm CWDM proposed by Wiedemann, 5/00
  - 3-PMD set proposed by Hanson, 5/00:
    1300 WWDM, 1310 Serial, 1550 Serial
- Target 850 nm Serial specifications are described
- Rationale on PMD optimization

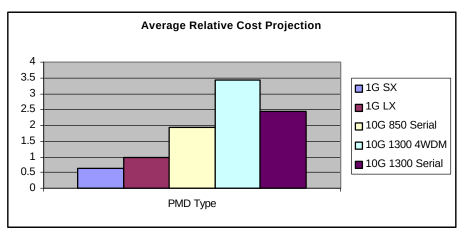
Critical Optimization Dimensions

- Cost
- Risk
  - Manufacturability
  - Time to Market
  - Market Acceptance
- Application Space Coverage
- Implementation Complexity
- Proven Technical Feasibility
- Multi-vendor support

Cost Optimization

- Must have low cost solution for short reach application
  - Most cost sensitive application space
  - The highest volume application space
  - 90% of 10GbE ports expected to be in enterprise
    - Source: Technical Essence Webs
- 92% of enterprise backbones <300 meters
- The 300 meter objective must be served with the lowest cost PMD for broad market acceptance
  - Historically SX technology is lowest cost
  - 80 - 90% of GbE market is SX (lowest cost and <300 m coverage)

Cost Projections from Reflector



PMD Type	Rich T.	Jack J.	Paul K.	Ed C.	Ave.
1 GbE SX PHY current cost	-	0.5	0.67	0.7	0.62
1 GbE LX PHY current cost	1	1.00	1.00	1	1.00
10 GbE Serial 850 nm in (2002)	2-3	1.25	1.50	2.5	1.94
10 GbE WWDM 1300 nm in (2002)	3-4	4.00	2.92	3.3	3.43
10 GbE Serial 1300 nm in (2002)	2-4	2.00	2.25	2.6	2.46

850 Serial projected to have the lowest cost.
850 CWDM cost claims competitive with 850 Serial.

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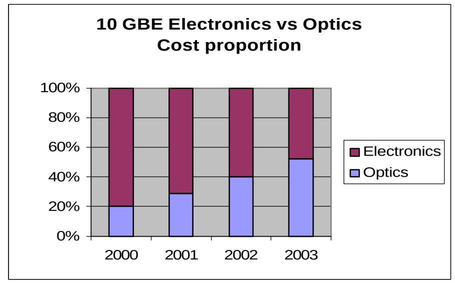
Intrinsic Cost Driver Comparison

Cost element	4λ WDM	850 Serial
Lasers & drivers	4 (λ-selected)	1
Detectors & amps	4	1
Optical alignments	10 SM/MM (5 Tx & 5 Rx) Offset Patch Cord	2 MM
Optical filters	4 or 8	0
Mux	1 optical	1 electrical
Demux	1 optical	1 electrical
IC speed	3.1 G	10.3 G

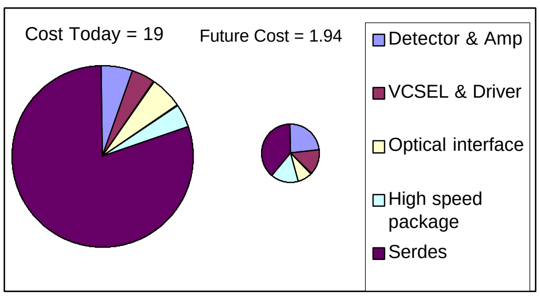
IC costs decline much faster than optics costs.
Optics costs drive total costs over time.

Optics cost drives total cost over time

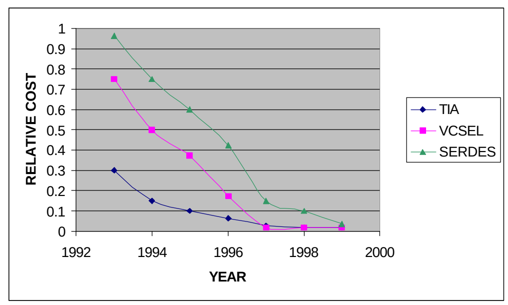


	Cost Reduction	Drivers
Electronics	50%/year	Moore's law, SiGe, CMOS
Optics	18%/year	Packaging improvements, materials cost reductions

SX Relative Costs: 10G / 1G

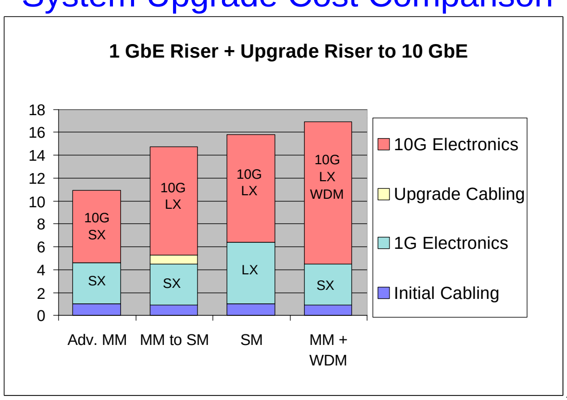


IC Cost Trends For 1G



ICs decline by factors of 20 to 30.
Average selling price of 1G SerDes Chip in 1999 is about the price of 2 beers per Dataquest.
These chips were several hundreds of dollars initially.

System Upgrade Cost Comparison



Risk Minimization

- Manufacturability
  - Introduction of new technologies can lead to unforeseen delays
    - Recent examples: Parallel Solutions and SFF Transceivers at 1G
  - 850 nm serial solutions are a direct evolution of existing technologies
- Time to Market
  - Lower risk technologies lead to faster time to market
  - Many IC and serial PMD vendors developing serial products
- Market Acceptance
  - End-users historically accept new media that provides new application coverage while retaining support for legacy systems
  - New MMF demand following same trend

Market Acceptance

- Customers already have installed next generation MMF

Lucent's LazrSPEED™ MMF available since January
Sample installations to date:

Agilent
BMW
Merrill Lynch
Nokia
Peco Genco
Pike's Peak College
University of Texas
Wells Fargo

Demand exceeding projections.

Other manufacturers to supply new MMF include:
Alcatel, Corning and Plasma

Market Acceptance

- Some reasons why customers install new MMF
  - End users believe that serial 850 will likely end up providing the lowest system cost.
  - The fact that cabling is a small part of the overall system cost today, and a decreasing fraction as speeds increase.
  - End users desire to manage legacy, current, and future applications on one fiber type. (SM is NOT backward compatible to the <1Gbs applications that most end users must support)
  - Aversion of end-users to installing difficult to terminate single mode fiber in buildings.
  - The relative ease with which building backbones can be upgraded.

Market Acceptance

- Sufficient PMD offering critical
  - Additional PMDs do not retard market
    - 100BASE-T2 / T4 / TX example:
      - **T2 and T4 targeted installed Cat 3 UTP**
      - **TX targeted new Cat 5 at lower cost**
      - **Only TX was accepted by market**
      - **Cat 5 rapidly displaced Cat 3 in more difficult to upgrade horizontals**
    - What would have happened to Ethernet without TX and Cat 5 UTP?
  - Offering sub-optimal solutions retards market
    - Example: A Humvee is an all-purpose vehicle, but unacceptable as one-size fits all solution
  - Market acceptance depends on how well we match solution to customer needs

Application Space Coverage

- Must have cost-optimized solution for short reach market
  - 850 nm Serial is optimized for 300 m application space
- Customers need sub-100m solutions
  - 10G application heavily used in equipment room.
  - While no survey of equipment room link lengths available, < 100 m capability sufficient for equipment clusters, so can reuse existing fiber with serial 850 nm solution.
  - Equipment room cabling is often point to point jumpers.
  - Cost of jumpers dwarfed by cost of new electronics.
  - New MMF can easily be deployed in equipment room for longer lengths.

Implementation Complexity

- Serial Optics less complex than WDM optics
- Serial approach requires more complex Integrated Circuits
  - Many IC vendors addressing design issues
  - Cost savings result from technology advancements (SiGe,CMOS), volumes and competition
- Optical complexity includes difficult to reduce overheads
  - alignment tolerances
  - parts count
  - hybrid assembly techniques
  - mode-conditioning patch cords for SMF optics on MMF
- Favorable to trade optical complexity for IC complexity

Proven Technical Feasibility

- Serial 850 nm technology repeatedly demonstrated feasible by multiple PMD and fiber vendors.
- Operational under worse-than-worst-case stress conditions
- Fiber bandwidth test method and laser launch conditions in fast-track development in TIA FO-2.2 aligned with IEEE schedule
  - Benefiting from 1G experience
  - System proposal in place, backed by powerful simulation capability
  - Participants include

    Agilent, Alcatel, Cielo, Compaq, Corning, GN Nettest, IBM Infineon, Lucent, Naval SWC, NIST, Nortel, Picolight, Plasma, Raytheon, Siecor
- Cabling standards agree to add new MMF specifications
  - See TR42 Liaison Letter to IEEE 802.3 and 802.3ae of May 19, 2000

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Technical Feasibility / Multi-Vendor Support

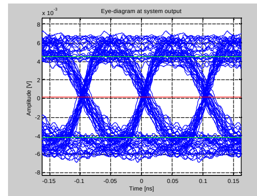
- Technical demonstrations performed by multiple companies

VCSEL / Fiber	Rate	Distance	Comments
Lucent	10 Gb/s	2800m	$<10^{-12}$ BER
Lucent	10 Gb/s	300m	$<10^{-12}$ BER, beyond worst case
Gore / Corning	10 Gb/s	600m	
Gore / Lucent	10 Gb/s	900m	$<10^{-12}$ BER
Cielo / Lucent	12.5 Gb/s	300m	$<10^{-14}$ BER
Picolight / Lucent	10 Gb/s	400m	$<10^{-12}$ BER
Gore / Alcatel	10 Gb/s	300m	
IBM / Gore / Lucent	10 Gb/s	500m	Robustness tested
New Focus / Lucent	10 Gb/s	300m	$<10^{-13}$ BER
Picolight / Corning	10 Gb/s	300m	

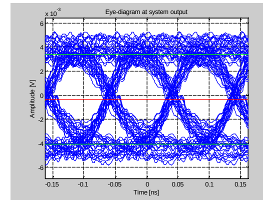
Ensures competition in market

Technical Feasibility - IBM Data

Back-to-back

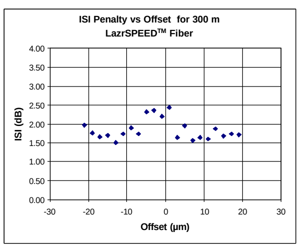


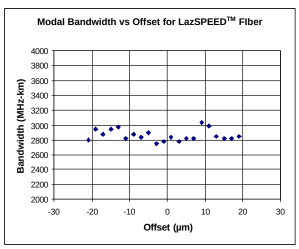
300 m LazrSPEED™



IBM LazrSPEED Lucent Technologies Bell Labs Innovations

Technical Feasibility - IBM Data





IBM LazrSPEED Lucent Technologies Bell Labs Innovations

Figure 38-1

- Almost the same as in 802.3z
- The mode conditioning patch cord does **not** apply

(802.3z Figure 38-1 shows PMA, PMD, Fiber Optic Cabling (channel) and four test points)

Table 38-2

Operating range for 10000BASE-SX over each optical fiber type

Fiber type	Modal BW @ 850 nm (min. overfilled launch except as noted) (MHz*km)	Minimum range (meters)
50 µm MMF	2000 [a]	2 to 300
50 µm MMF	500	2 to 86
50 µm MMF	400	2 to 69
62.5 µm MMF	200	2 to 35
62.5 µm MMF	160	2 to 28
10 µm SMF	N/A	Not Supported

a. Bandwidth and launch condition details being defined by TIA FO2.2.

Table 38-3

10000BASE-SX transmitter characteristics

Description	50 µm MMF	62.5 µm MMF	Unit
Transmitter Type	Shortwave Laser		
Signaling speed	10.3125 +/- 100 ppm		Gbd
Wavelength (λ, range)	840 to 860		nm
Trise/Tfall (max; 20%-80%)	31.5		ps
RMS spectral width (max)[a]	0.35		nm
Average launch power (max)	See note b.		dBm
Average launch power (min)	-5.5		dBm
Average launch power of OFF transmitter (max)	-30		dBm
Extinction ratio (min)[c]	6.5		dB
RIN (max)	-125		dB/Hz
Encircled flux @ r =15 µm in 50 µm fiber (min)[d]	85		%

a. Experimental evidence suggests larger values are supportable.
b. The lesser of class 1 safety limit or average receive power (max).
c. A change to Optical Modulation Amplitude (OMA) is proposed.
d. Measured per TIA/EIA 455-203 (draft). Subject to relaxation.

Table 38-4

10000BASE-SX receiver characteristics

Description	50 µm MMF	62.5 µm MMF	Unit
Signaling Speed (range)	10.3125 +/- 100 ppm		GBd
Wavelength (range)	840 to 860		nm
Average receive power (max)	-1.0		dBm
Receive sensitivity	-13.0		dBm
Return loss (min)	12		dB
Stressed receive sensitivity	-8.5	-7.6	dBm
Vertical eye closure penalty	2.5	3.0	dB
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

Table 38-5

Worst case 10000BASE-SX link power budget and penalties

Parameter	50 µm MMF			62.5 µm MMF		Units
Modal BW @ 850 nm (min. overfilled launch except as noted)	2000[a]	500	400	200	160	MHz-km
Link Power budget	7.5	7.5	7.5	7.5	7.5	dB
Operating Distance	300	86	69	35	28	m
Channel insertion loss	2.59	1.81	1.75	1.63	1.60	dB
Link power penalties	4.68	4.89	4.89	4.83	4.83	dB
Unallocated margin	0.23	0.80	0.86	1.04	1.07	dB

a. Bandwidth and launch condition details being defined by TIA FO2.2.

Table 38-10

10000BASE-SX link jitter budget

Compliance point	Total jitter		Deterministic jitter	
	UI	ps	UI	ps
TP1	0.24	23.3	0.100	9.7
TP1 to TP2	0.284	27.5	0.100	9.7
TP2	0.431	41.8	0.200	19.4
TP2 to TP3	0.170	16.5	0.050	4.8
TP3	0.510	49.5	0.250	24.2
TP3 to TP4	0.332	32.2	0.212	20.6
TP4	0.749	72.6	0.462	44.8

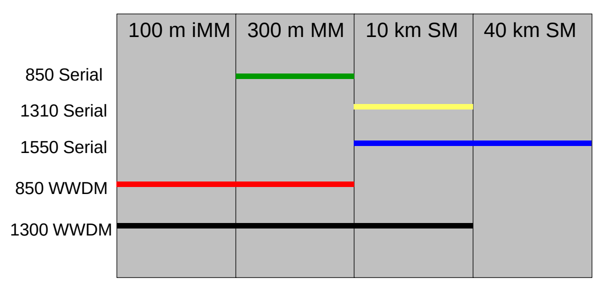
Notes and Further Work

- Notes
  - Used Piers Dawe's link model (version 041) with the following adjustments: MPN k factor = 0.5, baud rate for MPN beta, DCD_DJ = 9.7 ps except for New MMF DCD_DJ = 8.0 ps.
- Further Work
  - Target specifications at least 60% complete. Refinement work underway.

Summary

- Broad Market Potential / Application Space Coverage
  - Bulk of market is short reach. 10GbE must provide solution optimized for the <300 m application space.
- Economic Feasibility
  - 850-nm serial will be the lowest cost. As IC costs decline, cost determined by intrinsic optics complexity.
- Technical Feasibility
  - Serial 850 nm demonstrated more than any other emerging technology. Target specifications realistic. Direct evolution of existing technology provides low risk path.
- Multi-Vendor Support and Supply
  - Many companies supporting 850 nm serial technology. Ensures competition and product availability.

Coverage of Top 5-PMD Set



The fastest route to consensus