5 PMD Proposal and 850 nm Serial Specifications and Criteria

Presented By

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List of Supporters
63 Individuals, 26 Companies

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Bill Wiedemann, Blaze
Rob Williamson, New Focus
Tony Whitlow, Molex
Mike Witkowski, Compaq
Jason Yorks, Cielo
Len Young, Corning

Objectives

- 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
- Show how this proposal meets the 5 Criteria

Target Specifications for Clause 53

(Clause 38 style)

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 10GBASE-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.

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Table 38-3

10GBASE-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 =16 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).

Table 38-4

10GBASE-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 10GBASE-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

10GBASE-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.
  - Practical transmitter output power range needs either Eye Safety relaxation (in final ballot in IEC) or OFC.
- Further Work
  - Target specifications complete. Refinement work underway.

Criteria 1
Broad Market Potential

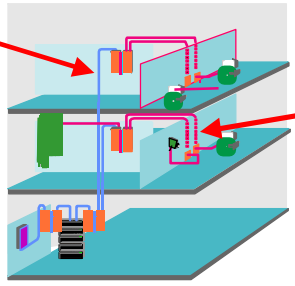
- Installed Base Conversion to New MMF
- Market size and "short-reach" share
- Market Acceptance
- Customer testimonials

Structured Cabling Solutions

Building Backbone

2000 New MMF

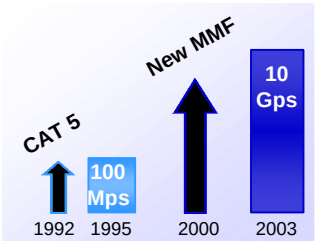
10 Gbps



Horizontal

1992 CAT 5 UTP

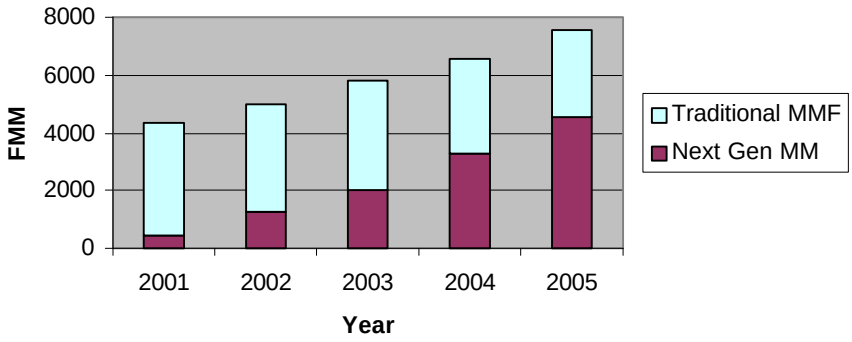
100 Mbps



- **Cable usually installed at least 3 years before switch upgrade**
- **New MMF Shipping since Jan 2000**
- **VERY positive customer response**

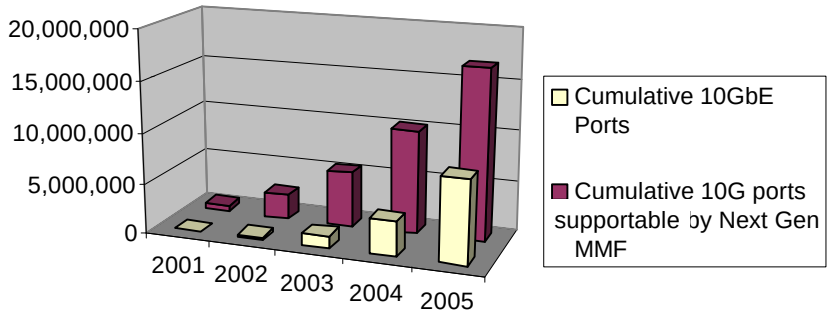
MMF Market Projection

MMF Annual Sales



Based on KMI Projection for Global Total Multimode Market

10GbE Ports Shipped and Supported



- 8M Ports by 2005*
- Could support up to 17M** 10 GbE ports by 2005

* Derived from Technical Essence Webs presentation to IEEE 9/99.

** Assumes 75% dark fiber, 170m average link length.

Short Reach Market Size

- 90% of 10GbE ports expected to be in enterprise
  - Source: Technical Essence Webs
- 92% of enterprise backbones <300 m
  - Source: IEEE 802.3z (GbE) Survey
- 83% of ports are short reach (90% x 92%)
  - 6,600,000 Ports thru 2005
- Most cost sensitive application space.
  - The 300 meter objective must be served with the lowest cost PMD for broad market acceptance
  - Historically SX technology is lowest cost
- End-users historically accept new media that provides new application coverage while retaining support for legacy systems

Market Acceptance

- Market acceptance depends on how well we match solution to customer needs
- Are PHY & PMD choices complexities or features?
  - Customer choices go well beyond PHY and PMD today
    - Routing protocols
    - Security options
    - Data rates
    - Media adapters / converters
  - Customers can select appropriate PHY and PMD with a little guidance
    - LAN or WAN?
    - SM or MM?

Customer Testimonial 1

"We have installed the [new multimode] fiber because it supports legacy and gigabit applications and low-cost 10 Gigabit Ethernet at 850 nm."

Kurt Bartelmehs, who is in charge of the network for University of Texas-Austin

Customer Testimonial 2

"At Nokia Saterinportti-premises (Espoo, Finland), we have installed Lucent [new multimode] fiber to the backbone network for future 10 Gbit needs.

Saterinportti-premises is a building consisting of 5 blocks and is designed for up to 2000 people."

Markku Niemi, IT Facilities Manager, Nokia

Customer Testimonial 3

"I support at least one low cost LAN PMD solution and if the 850 nm serial PMD turns out to be the one, then I support it.

Further, I don't like having to use mode conditioning patch cables.

Pulling new fiber intra-building is no problem for us, so I don't perceive this as a forklift upgrade."

Mike Bennett, Lawrence Berkley Labs

Customer Testimonial 4

"To prevent the proliferation of customized solutions and the resultant interoperability problems, IEEE 802.3 should standardize on an optimized, high-volume, short-reach PMD for our customer requirements.

I believe this solution is best achieved with 850 nm technology and multimode fiber.

This approach is compatible with legacy applications, while providing reasonable reach and a degree of future proofing when combined with the new high bandwidth multimode fiber."

Dave Hyer, Senior Member Technical Staff, Compaq

Customer Testimonial 5

"IEEE 802.3ae needs to standardize a low-cost 850 nm PMD.

In data centers, the construction cost for singlemode fiber plant is 4 times the cost of multimode.
Ribbon interconnects in the data center, such as OIF or Infiniband, are not acceptable due to the inability to field-terminate ribbons.
The mode-conditioning patch cords are unacceptable due to high cost and complexity added to the cable plant.

I would much rather have IEEE standardize on 850-nm PMDs for 10 gigabit Ethernet than have many proprietary 850 nm PMDs."

Roy Bynum, Network Architect.

Criteria 2
Compatibility with Standard 802.3

- PMD / PCS interface defines compatibility with higher layers for all PMDs.
- Specifications confirmed with accepted link model
- New MMF supports all previous Ethernet fiber PMDs
  - 10BASE-FL
  - 100BASE-FX
  - 1000BASE-SX
  - 1000BASE-LX w/o mode-conditioning patch cords

Criteria 3
Distinct Identity

- 5 PMD set overlaps objectives, but each solves unique problem

Problem	Optimal Solution
Longest Distance (40+ km)	1550 Serial
Med. reach, lower cost, transponder compat.	1310 Serial
Max reuse of installed MMF	1310 WDM
Lower cost for installed MMF	850 WDM
Lowest cost on MMF	850 Serial

Applying Optimal PMDs

PMD Comparisons between 1 GbE and 10 GbE proposals

Application	Distance / Media	Lowest Cost Solution		2002 Normalized Cost Comparison For 10 GbE PMDs (normalized to 1000BaseLX)
		GbE	10 GbE	
1. Box-to-Box or Intra-Closet Interconnects	<25 meters, media interchangeable	**1000BASE-CX on Twinax**	**850nm Serial on iMMF**	1.94
2. Horizontal / Eq Rm	100 meters	**1000BASE-T on Cat5**	**CWDM on iMMF**	
3. Riser	220 meters on iMMF	**1000BASE-SX**		
	300 meters on MMF		**850nm Serial on nMMF** *WWDM on iMMF w/ PC*	1.94 *3.43**
	500 meters on iMMF	**1000BASE-LX w/ PC**		
4. Campus	5 km on SMF	**1000BASE-LX**		
	10 km on SMF	*Enhanced 1000BASE-LX*	**1310nm Serial**	2.46
5. MAN / Inter-campus	40 km on SMF		**1310nm Serial (EPB)**	
	80 km on SMF	*1550nm PMDs*	*1550nm Serial*	
Total Number of PMDs		**4** / *6*	**4** / *6*	

Bold Plain Text = Standardized
Italicized = Non-standard implementations or in excess of PAR requirement
PC = Patch Cord EPB = Enhanced Power Budget CWDM = 850nm Coarse WDM WWDM = 1310nm Wide WDM
*Does not include cost of offset patch cord

802.3 must Specify Short Reach

- Some argue to let other bodies define short reach
- Par specifies 100 m objective - this is short reach.
- 802.3 has always defined short reach solutions. Examples:

1000BASE-CX	25 m
1000BASE-T	100 m
1000BASE-SX	220 - 550 m
100BASE-T2 / T4 / TX	100 m
10BASE-T	100 - 150 m

- Ethernet is >90% of all LAN market. Must define own PMDs.
- System vendors sampling 10G 850 nm VCSELs.
  - At least 7 are in the 10GbE business
  - Without standard we invite proliferation of proprietary non-interoperable solutions
  - There are at least 30 PMD companies. How many proprietary solutions?

Criteria 4
Technical Feasibility

- 850 Serial CWDM presentations to IEEE (~34).

Company	Number of Presentations
Alcatel	1
Blaze	5
Cielo	1
Corning	3
Gore	2
Finisar	2
Honeywell	1
IBM	1
Lucent	10
New Focus	2
NetWorth	4
Picolight	2

- New data at this meeting from New Focus
- Competitive PMDs lead to more robust specifications thru checks and balances in the standards process

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

Demonstrated Multi-Vendor Support

- 850 nm Serial Demonstrations

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	

1310 WWDM demonstrated by only one company

Criteria 5
Economic Feasibility

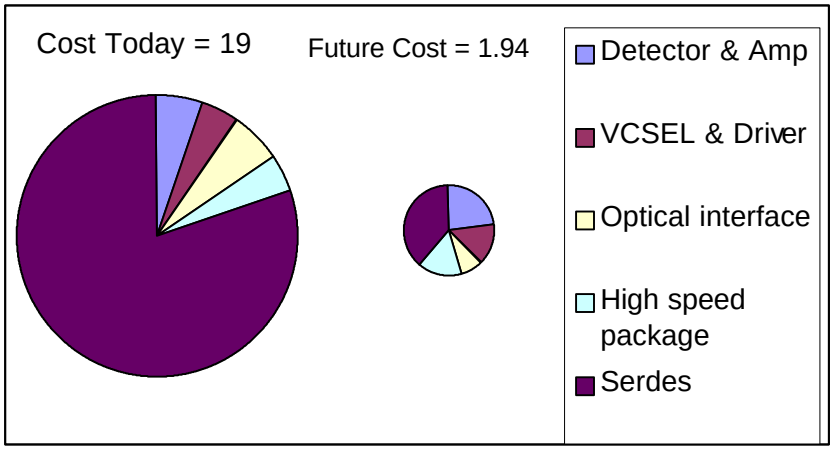
- 850 Serial is simplest design
  - Lowest component count
  - Easy-to-test VCSELs
  - Multimode not Singlemode alignments
- SerDes is same as 1310 Serial
  - Volumes and competing processes (CMOS, SiGe) will drive prices down
- New MMF upgrade cost is smaller than cost difference between transceiver types
  - Upgrading pays for itself.
  - New MMF uses same familiar installation tools, procedures, and test kits.
    - Saves retraining and installation time. Improves termination yield.
    - Key factors in Data Center and CO build-outs

Intrinsic Cost Driver Comparison

Cost element	4λ WWDM	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.

SX Relative Costs: 10G / 1G



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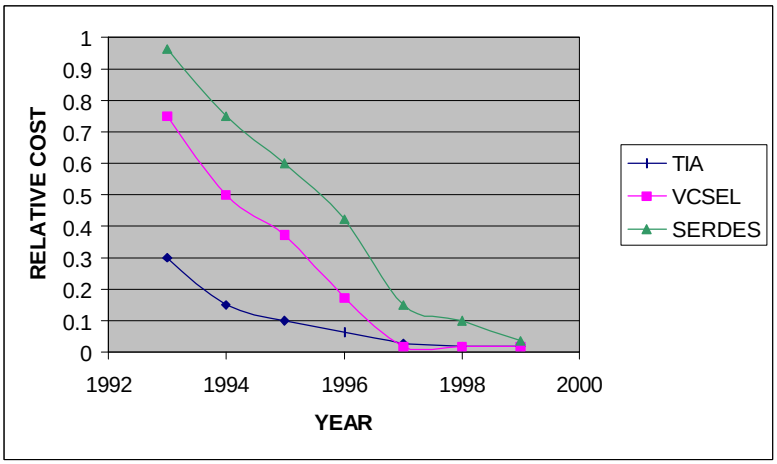
IC Cost Trends For 1G



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.

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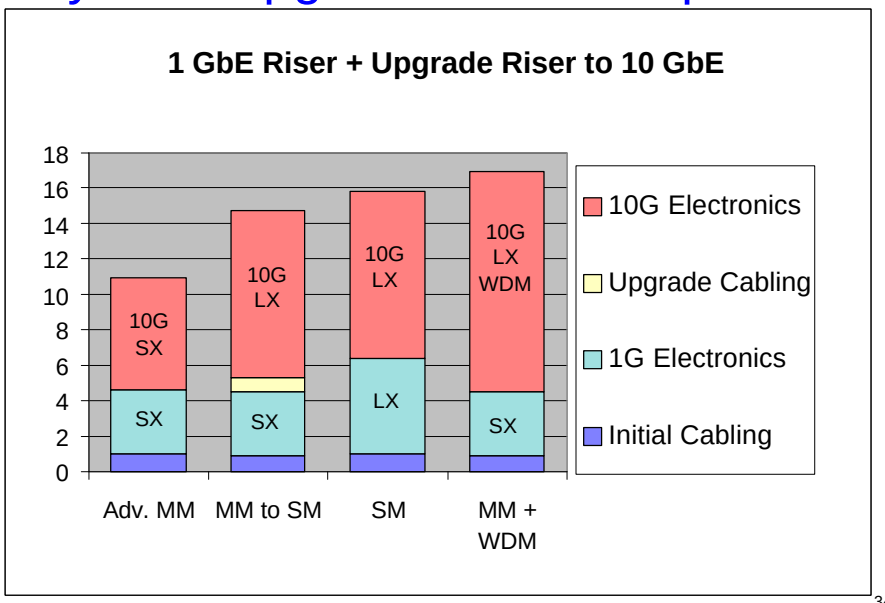
System Upgrade Cost Comparison



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Consensus Direction - 5 PMDs

- March motion calls for down selecting to 7 or fewer PMDs by July. Choosing 5 PMDs more than meets this requirement.
- The 5 PMD set is inclusive of the 3 PMD set. Non-exclusionary position to aid consensus building. No delay.
- Too soon to discard any of these 5 PMDs. Need more time to allow better assessment of choices. Otherwise risk elimination of market favorite, inviting proliferation of proprietary solutions that create market barriers.
- Consider motion to adopt these 5 PMDs with proviso that they each must meet specific criteria by WG Ballot.
  - Multiple vendors sampling parts compliant to draft specs.
  - Demonstrated compliant BER at maximum link lengths.