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10x10G WDM 10km SMF PMD Proposal

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Supporters

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- Ralf-Peter Braun – Deutsche Telekom
- Frank Chang – Vitesse
- Pierangelo Chiappa – Alcatel-Lucent
- Xavier Clairardin – Kotura
- Keith Conroy – AMCC
- Chiwu Ding – Huawei Technologies
- Michael Frankel – Ciena
- Ali Ghiasi – Broadcom
- Wenbin Jiang – Huawei Technologies
- Scott Kipp – Brocade
- Bikash Koley – Google
- Zeng Li – Huawei Technologies
- Hong Liu – Google
- Arlon Martin – Kotura
- Ye Min – Huawei Technologies
- Shantanu Mitra – Netlogic
- Phil McClay – Zarlink
- Robert Snively – Brocade
- Siddharth Sheth, Netlogic

IEEE802.3ba Objectives

IEEE P802.3ba Objectives

- Support full-duplex operation only
- Preserve the 802.3 / Ethernet frame format utilizing the 802.3 MAC
- Preserve minimum and maximum FrameSize of current 802.3 standard
- Support a BER better than or equal to 10^{-12} at the MAC/PLS service interface
- Provide appropriate support for OTN
- Support a MAC data rate of 40 Gb/s
- Provide Physical Layer specifications which support 40 Gb/s operation over:
  - at least 10km on SMF
  - at least 100m on OM3 MMF
  - at least 10m over a copper cable assembly
  - at least 1m over a backplane
- Support a MAC data rate of 100 Gb/s
- Provide Physical Layer specifications which support 100 Gb/s operation over:
  - at least 40km on SMF
  - at least 10km on SMF
  - at least 100m on OM3 MMF
  - at least 10m over a copper cable assembly

Updated by IEEE P802.3ba Task Force and approved by 802.3 at March 2008 Plenary 1

Applicable SMF Alternatives
from HSSG Adhoc

SMF	10km 1310nm	40km 1310nm	10km 1550nm	40km 1550nm
10x10G DML	yes + CL	yes + CL + OA	yes	maybe + OA
10x10G ML	yes + CL	yes + CL + OA	yes	yes + OA
5x20G / 4x25G DML	yes	maybe + OA	maybe	maybe + DC
5x20G / 4x25G ML	yes	yes + OA	yes	yes + DC
2x50G DQPSK I/Q ML	yes + CL	yes + CL + OA + DC	yes + CL + DC	yes + CL + OA + DC
1x100G TDM ML	yes + CL + OA	yes + CL + OA + DC	yes + CL + OA + DC	yes + CL + OA + DC

CL = Cooling (or semi-cooling,) OA = Optical Amplification, DC = Dispersion Compensation

Green shading designates alternatives under detailed study by Fiber Optic Ad Hoc contributors

Red Rectangle highlights scope of this presentation

From dove_01_0407.pdf Fiber Optic Adhoc Report

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Outline

- Objective
- Why another proposal?
- What?
- Link Budget
- Power Dissipation Budget
- Cost
- Technical feasibility results

Discussion Objective

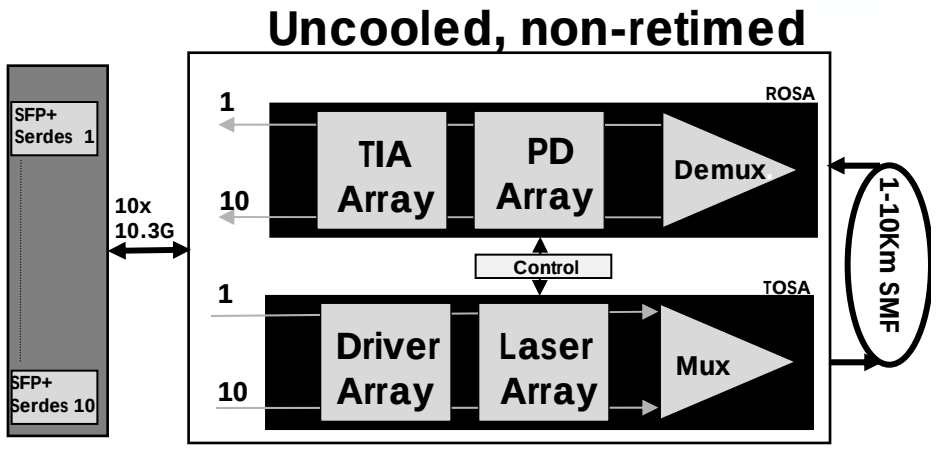
- Input from service provider and data center end-user community
  - 100G system development timing is now
    - Large percentage use Nx10G LAG today
    - Pushing the limits of LAG by 2009-2010
  - Has aggregation needs of 10GEPON been captured in the market size?
- Proposing 10x10Gb/s WDM PMD for 10km SMF
  - Propose link and power budget
  - Proof of concept, test results
- Task Force to approve 100G 10x10G PMD for 10km SMF
  - 10x10G has shortest time to market and lowest cost
  - 10x10G has lowest power dissipation, enabling highest port density
  - Synergy with other nx10G PMD proposals simplifies PMD choices

Proposal Overview

- 10km of SMF
- 10x10Gb/s architecture
- 8nm wavelength grid
- Centered at 1550nm for lowest fiber loss: 1523nm – 1595nm
- Low ER to enable lower cost DML solutions
- Compatible with integrated array of WDM DFB
- Compatible with integrated optical Mux and DeMux
- Uncooled operation

Justification for Time to Market and Cost

- Nx10G infrastructure and food chain in place
  - Leverage 10G cost curves and multiple vendors
- Re-use commercially proven array components to deliver lowest cost
  - Laser arrays commercially deployed in carriers since 2004*, with proven reliability
  - Driver, TIA and PD array
  - Leverage 10G test and manufacturing infrastructure
  - 10GEPON market will drive 10G components to higher volumes and lower cost
- Shared components/Synergy with 10x10G MMF, similar technology as 4x10G
- Experience with previous operating speed indicate that high level of component integrations will be required to reduce cost



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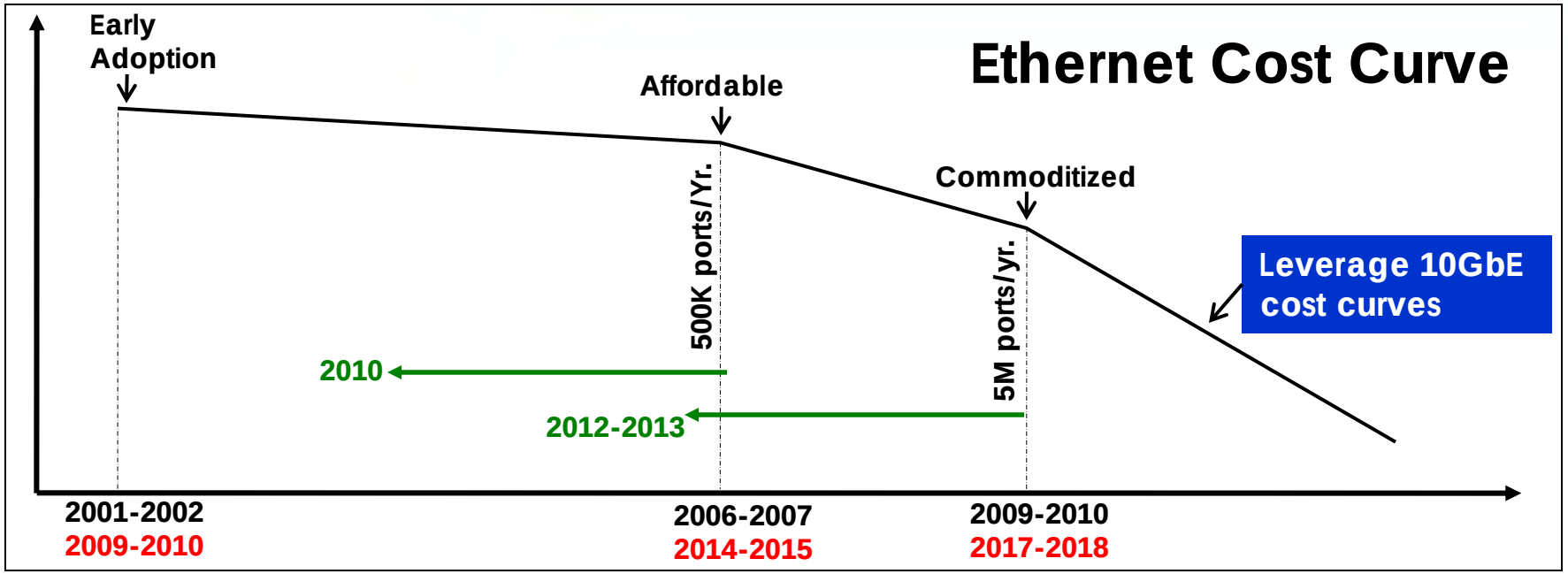
Leveraging 10G Cost Curves Accelerates 100G Adoption



- Starting with lower cost per port **accelerates** adoption
- Gap to commodity cost narrows
- Only lowest cost optics will be used for high volume 100GbE

Link Budget (Re-use of 10GBASE-ER)

Chip to chip OMA link budget (dB)		10x10Gb/s 1550 WDM 10km ER=3.5dB		10GBASE-ER 30-40km ER=3dB	
Laser Chip → SMF (TP2)		6.5		3.0	
Link Budget (TP2→TP3)	Fiber Loss	2.9		8.9	10.9
	Connector Losses	2.0		2.0	
	CD Penalty	1.5		4.1	
	Other Penalties	0.7			
	Total	**7.1**		**15.0**	
SMF →PD chip		4.5		1.0	
Crosstalk Penalty		1.0		0.0	
Total LD→PD		19.1		19.0	

- Proposed chip to chip budget is equivalent to 10BASE-ER chip to chip budget
- Additional channel insertion loss for 40km is replaced by Mux/Demux loss
- Path penalties are equivalent: 40km dispersion ≅ 10km dispersion + crosstalk

Fiber loss from FOAH_anslow_01_0407

10km SMF OMA Link Budget

			From cole_01_0308		From traverso_01_0308	
100GbE SMF 10km Loss TP2 → TP3 in dB	**10x10Gb/s 1550 WDM ER=3.5dB**	**4x25Gb/s LAN WDM**		**4x25Gb/s CWDM**	
		C-EML ER=7dB	**C-DML ER=4.5dB**	**C-EML ER=7dB**	**UC-EML ER=7dB**
Fiber Loss	2.9	4.2		4.7	4.7
Connector Losses	2.0	2.0		2.0	
CD Penalty	1.5	0.3	1.3	1.3	1.3
Other Penalties	0.7	0.7		0.7	
Total	**7.1**	**7.2**	**8.2**	**8.7**	**8.7**

(CD+connector+other=4dB)

Note: CWDM budget removed 1dB ER penalty for OMA budget (9.7dB → 8.7dB)

10km SMF OMA Power Budget

			from cole_01_0308		from traverso_01_0308	
100GbE SMF 10km OMA in dBm	**10x10Gb/s 1550 WDM ER=3.5dB**		**4x25Gb/s LAN WDM**		**4x25Gb/s CWDM** translated to OMA	
			C-EML ER=7dB	**C-DML ER=4.5dB**	**C-EML ER=7dB**	**UC-EML ER=7dB**
Tx Min → Max	3.1→6.1		2.0→5.0	3.0→6.0	2.4→5.4	2.4→5.4
TP2 Tx (1)	-3.4		-0.5	0.5	-0.1 (1.0)	-0.1
Link Budget (dB)	7.1		7.2	8.2	8.7	8.7
TP3 Rx Min	-10.5		-7.7	-7.7	-8.8 (-7.7)	-8.8
Rx Min (1)	-15.0		-10.2	-10.2	-11.3 (-10.2)	-11.3
Rx Min with Xtalk=1dB	-16.0		-11.2	-11.2	-12.3 (-11.2)	-12.3
TP2 Max P_{av} all λ's (2)	10.8		7.3	9.7	7.7	7.7

(1): 4 channel Mux/DeMux Loss = 2.5dB; 10 channel Mux/DeMux Loss = 6.5/4.5dB
(2): 4 channels = 6dB; 10 channels = 10dB

Transceiver Power Dissipation (1st Gen)

10 x 10Gb/s WDM	1st Gen 10x10 I/O (w retimed interface)		
	Tx Type	Uncooled DML	
	TOSA	10x	0.5
	Driver	Discrete	4.5
	ROSA + TIA	10x	0.5
	CDR	Dual/Quad	2.5
	Other ICs		0.5
	Power Dissipation		**8**
	Size	Double XENPAK Width	
	1st Gen w/o retimed interface		
	Power Dissipation		**5.5**
	Size	XENPAK Width	

LAN WDM	4x25Gb/s 1st Gen 10x10 I/O		
	Tx Type	Cooled EML	
	TOSA	Quad	4.5
	Driver	Quad	2.0
	ROSA + TIA	Quad	1.2
	Gear Box	SiGe	6.5
	Other ICs		0.5
	Power Dissipation		**14.7**
	Size	Double XenPak Width	
	cole_01_03_07		

CWDM	4x25Gb/s 1st Gen 10x10 I/O		
	Tx Type	Cooled EML	
	TOSA	Discrete	4.0
	Driver	Discrete	4.8
	ROSA + TIA	Discrete	1.2
	Gear Box	SiGe	8.0
	Other ICs		
	Power Dissipation		**18**
	Size	Double XenPak Width	
	traverso_01_0308 Shows path to 11W And 9W for 4x25G I/O		

Note: All power dissipation numbers are in W

Transceiver Relative Cost

10x10G 10km Cost				4x25G 10km Cost			
10GBASE-LR XFP	**Cost**	**10km 10x10G Xcvr**	**Cost**	**10GBASE-ER XENPAK**	**Cost**	**10km 4x25G Xcvr**	**Cost**
CDR	0.75X	10x CDR	2X	XAUI	1X	Gear Box	3X
LDD	0.5X	10x LDD	2X	MD	1X	Quad MD	3X
TOSA	0.33X	10x TOSA With Mux	1X	TOSA	1X	Quad TOSA with Mux	4X
ROSA	1X	10X ROSA with DeMux	2X	ROSA	1X	Quad ROSA with DeMux	4X
Other	0.5X	Other	1X	Other	1X	Other	2X
1ch Testing	1X	10ch Testing	1X	1ch Testing	1X	4ch Testing	1X
Weighted Average	**0.5X**		**1.5X**	**Weighted Average**	**1X**		**4X**
Without CDR			**1X**	cole_01_0307			

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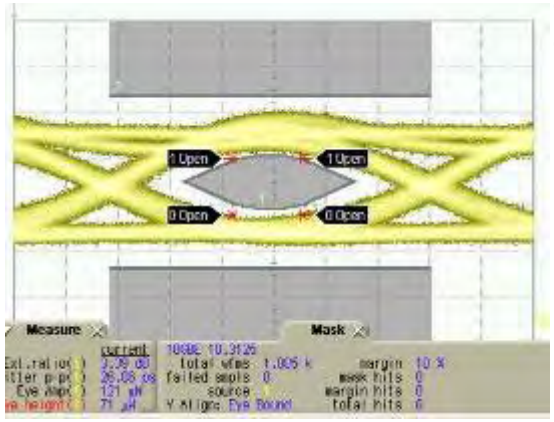
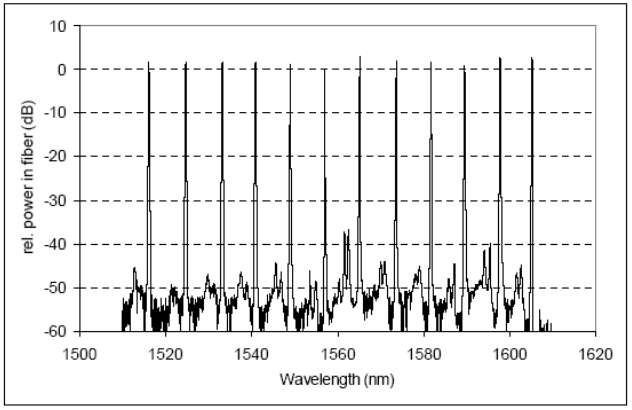
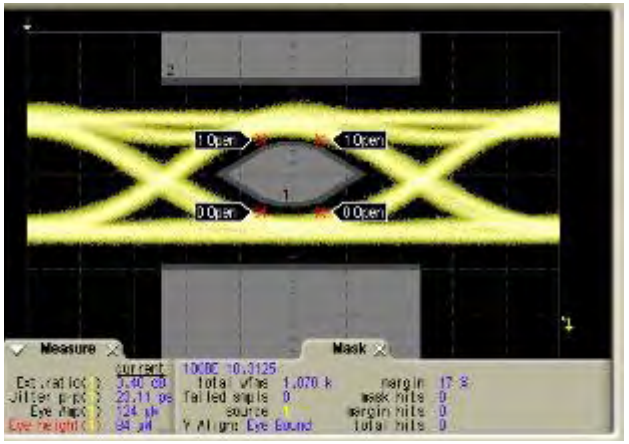
Laser Array Performance



80 ^{0}C
85mA bias
L1

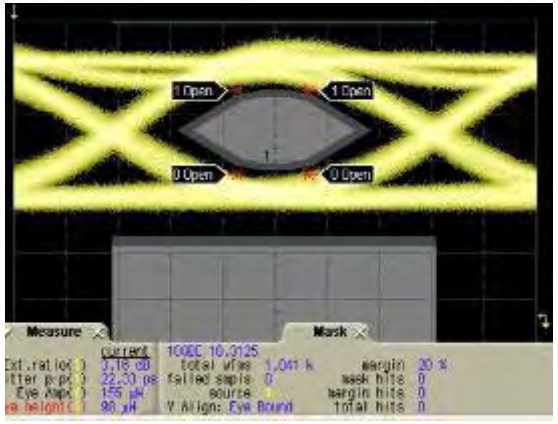


80 ^{0}C
60mA bias
L5



80 ^{0}C
60mA bias
L6

80 ^{0}C
60mA bias
L10



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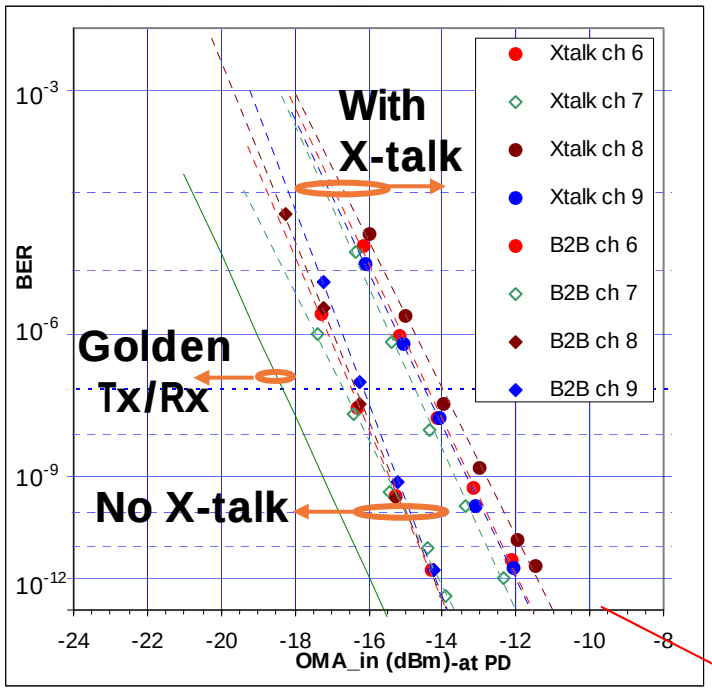
Receiver Crosstalk Performance

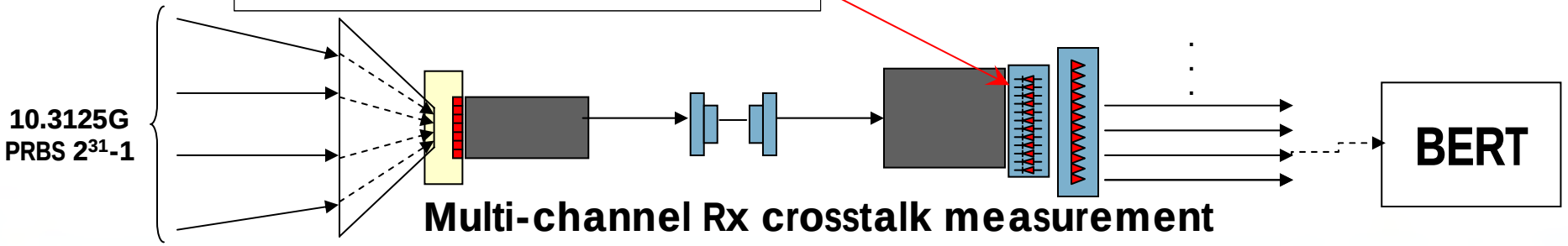


Laser Array

PLC

TIA Array

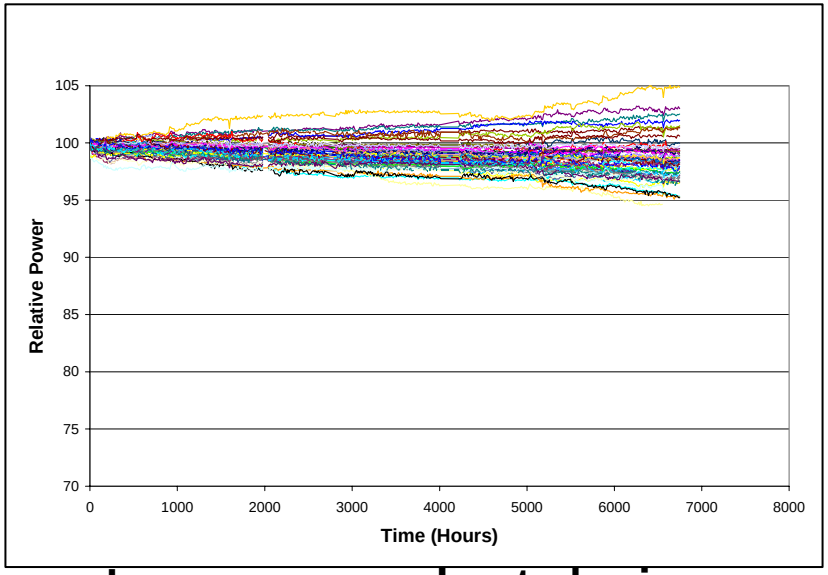
PD Array



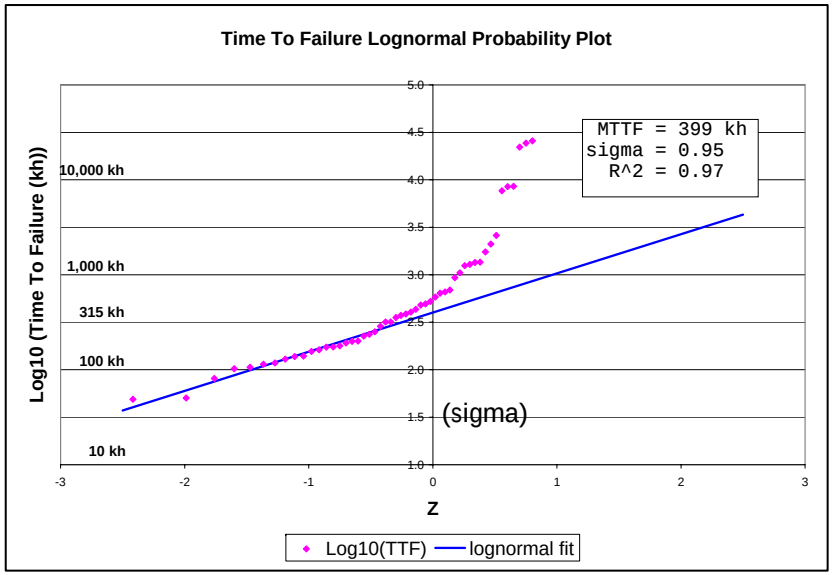
Multi-channel Rx crosstalk measurement

Proven DFB Array Reliability

- Extrapolated FIT rate < 1 in 20 years (single laser per array)
  - Worst case for 10 lasers per array: 10 FIT in 20 years
- Santur observation: no wear-out seen in >1 billion field hours
  - > 100 million field hours for 10x array



Laser array accelerated aging
64 channels, 100°C, 350mA (700μm)



MTTF probability plot

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10x10Gb/s Scalable to other 802.3ba PMDs

- 40Gb/s 10km SMF
  - Use 8nm grid and reduced wavelength range
  - Use same wavelength range with increased wavelength grid of 20nm
    - Increased uncooled temperature range, lower cost Mux/Demux
  - Re-use of same LDD, TIA, PD cells

- 100Gb/s 40km SMF
  - Additional Channel Insertion Loss compared to 10km
    - 30km x 0.29dB/km = 8.7dB
  - 1550 EML
    - 3.5dB ER to 7dB ER → gain of 2.4dB in OMA without increasing P_{max}
  - Additional Channel Insertion Loss is partially compensated resulting in needing 6.3dB more gain
  - This 6.3dB can easily be achieved with APD, FEC/EDC, SOA

Conclusion

- Propose a 10x10G 1550nm WDM 10km SMF PMD
  - Scalable to 4x10Gb/s over 10km SMF
  - Scalable to 10x10Gb/s over 40km SMF
- Demonstrated technical feasibility
- This proposal is the lowest cost, lowest power, uncooled solution
  - Proven 10G laser arrays (performance and reliability)
  - Leverage 10G cost curves, adopt Nx10G common scheme
- Uses viable, proven electro-optical components based on known specification methodologies
- Leverages common components, technologies, testing and manufacturing infrastructures with 100G 10x10 MMF PMD's and 40G 4x10 SMF/MMF PMD's