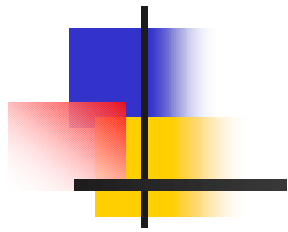


# 10GBASE-S Technical Feasibility RECAP



**Picolight**

**Corning**

**Cielo**

**CDT-Optical**

**Stratos**

**Lucent**

**Lightwave**

**IBM**

IEEE P802.3ae Austin, TX  
November 2001 Plenary meeting



## 10GBASE-S Feasibility supporters

---

- Bob Grow, Rich Taborek, Intel
- Raj Savara, Network Elements
- Vipul Bhatt, Finisar
- Krister Fröjdh, Optillion
- Paul Bottorff, Nortel Networks
- Ben Brown, Tom Palkert, AMCC
- Terry Cobb, Avaya
- Eric Grann, Blaze
- Rick Rabinovich, Spirent
- Justin Chang, Quake Technologies
- Philip Auld, EMCORE
- Jim Tatum, Honeywell
- Jeff Warren, Extreme



# Contents

---

- Interoperability report
- Compliance report
- Public demonstrations
- Results and summary
- Progress since October

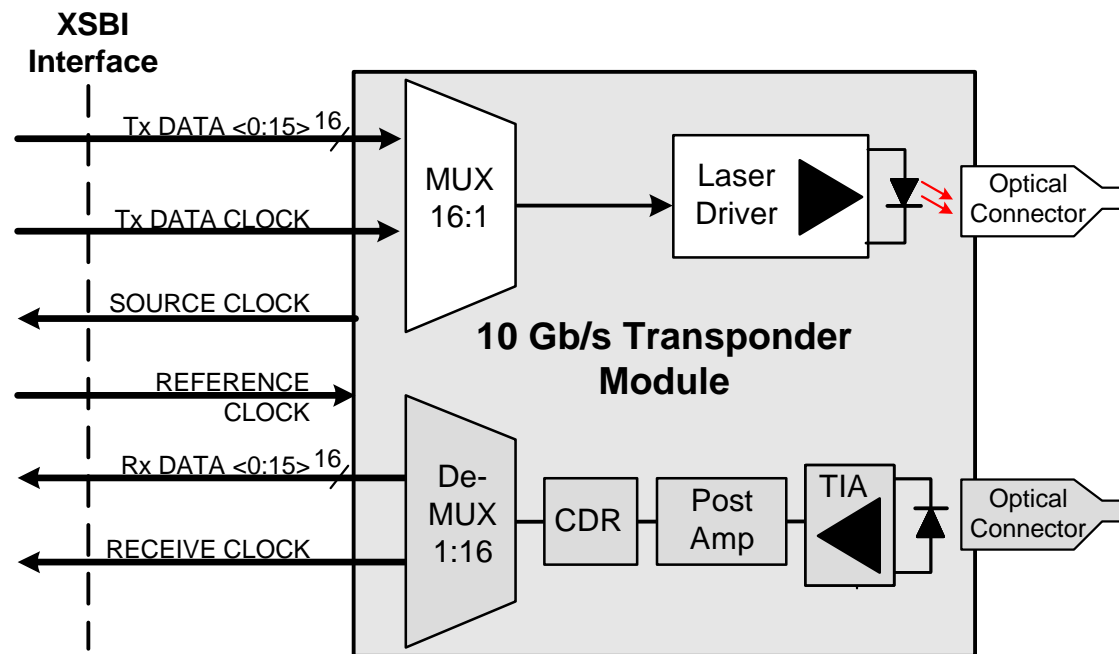


# Technical feasibility

---

- Demonstration of compliance or credible path to compliance to 10GBASE-S D3.3 specifications
- Interoperability test using 10GBASE-SR transponders using  $2^{23}-1$  PRBS data
- Parameter measurements and performance testing based on IEEE P802.3ae D3.3 specification

# Transponder functional block diagram



- XSBI interface
- Directly Modulated 850 nm VCSEL



# Interoperability test description

---

- Two 10GBASE-S PMA/PMD modules (Vendor A & B) connected over complete set of 50 $\mu$ m and 62.5 $\mu$ m fiber types operating at 10GBASE-R rate
- Module electrical interfaces defined by XSBI specifications (clause 51)
- Optical link stressed using excess optical fiber length

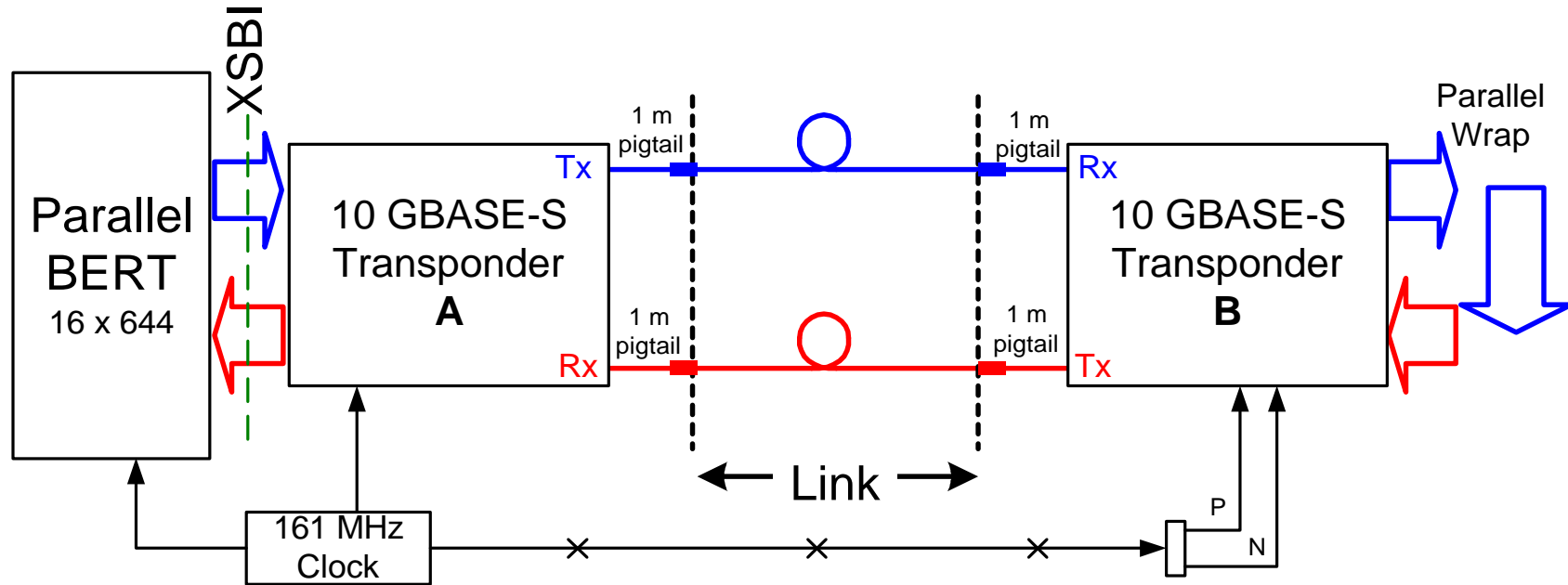


# Target Link Distances and Fiber Types

<b>Core Diameter</b>	<b>Modal Bandwidth (MHz-km)</b>	<b>Target Distance</b>
62.5 m	160	26 meters
62.5 m	200	33 meters
50 m	400	66 meters
50 m	500	82 meters
50 m	2000	300 meters

Link distance based on fiber types as specified in IEEE 802.3ae draft document

# Block diagram of test setup



Test Pattern: PRBS  $2^{23}-1$

Signal Speed 10.3125Gbps



# Interoperability testing results

Cable label	Fiber type	Length	Connector	# ofmFibers	Jumpers	Results	Comments
A	2000 MHz-km	300	SC	2		8.00E-13	
	2000 MHz-km	300				0	
B	2000 MHz-km	300	SC	2		0	
	2000 MHz-km	300				0	
D	2000 MHz-km	300	LC	2	2 x FC to LC 1 m jumper (62.5 um receive, 50 um transmit)	0	
	2000 MHz-km	300			2 x FC to LC 1 m jumper (62.5 um receive, 50 um transmit)	3.00E-13	
F	50 um - 400 MHz-km	66	SC	1		0	Near worst case (+/- 50 MHz)
G	62.5 um - 160 MHz-km	26	SC	1	2 m SC-SC jumper added (tension relief)	0	Near worst case (+/- 50 MHz)
H	50 um - 500 MHz-km	82	SC	1	2 m SC-SC jumper added (tension relief)	0	Near worst case (+/- 50 MHz)
I	62.5 um - 200 MHz-km	33	SC	1	2 m SC-SC jumper added (tension relief)	0	Near worst case (+/- 50 MHz)
J	50 um	66	SC	2		0	
	50 um	66				0	
K	62.5 um	35	SC	2	2 m SC-SC jumper added (tension relief)	4.90E-13	
	62.5 um	35			2 m SC-SC jumper added (tension relief)	0	
L	2000 MHz-km	360	SC	2	DMD 0.118 (0-23 um)	4.00E-13	
	2000 MHz-km	360			DMD 0.282 (0-23 um)	<1E-12	
M	2000 MHz-km	450	SC	2	DMD 0.119 (0-23 um)	<1E-12	
	2000 MHz-km	450			DMD 0.145 (0-23 um)	<1E-12	



# Testing summary

Fiber Type/ Bandwidth	Distance	% of link length	BER
62.5 $\mu\text{m}$ MMF 160 MHz·km	26	100%	$<10^{-12}$
62.5 $\mu\text{m}$ MMF 200 MHz·km	33	100%	$<10^{-12}$
50 $\mu\text{m}$ MMF 400 MHz·km	66	100%	$<10^{-12}$
50 $\mu\text{m}$ MMF 500 MHz·km	82	100%	$<10^{-12}$
<b>50 mm MMF 2000 MHz·km</b>	<b>450 m</b>	<b>150%</b>	<b><math>&lt;10^{-12}</math></b>



# Vendor A performance data

---

# Link Parameters (Vendor A)

## Transmit Characteristics

Description	Value Part 1	Value Part 2	Measured	Compliance with 802.3ae	Notes
Data Rate	10.3125 Gbps	10.3125 Gbps	Yes	Yes	
Clock Tolerance	< +/-100 ppm	< +/-100 ppm	No	Yes	Note 1
Wavelength	853.1 nm	852.2 nm	Yes	Yes	Note 2
RMS Spectral Width	0.2 nm	0.2 nm	Yes	Yes	Note 2, 4
Ave Optical Power	-5.6 dBm	-3.6 dBm	Yes	Yes	
Trise/Tfall	29 psec	33.2 psec	Yes	Yes	20% - 80% Note 3
OMA	0.370mW (-4.32 dBm)	0.582mW (-2.37 dBm)	Yes	Yes	Peak-peak Note 2
RIN <sub>12</sub> OMA	-135 dB/Hz	-135 dB/Hz	Yes	Yes	Note 5
Ave launch power of OFF transmitter	-80 dBm	-80 dBm	Yes	Yes	
Extinction Ratio	7.2 dB	7 dB	Yes	Yes	



# Link Parameters (Vendor A)

## Transmit Characteristics (continued)

---

Description	Value	Measured	Compliance with 802.3ae	Notes
Encircled Flux @ 19um	95%	Yes	Yes	Note 5
Encircled Flux @ 4.5um	10.3%	Yes	Yes	Note 5

Note 1: Based on vendor specification

Note 2: Compliant with triple trade-off table specified in draft 3.2

Note 3: Values are for the slower time,  $T_{fall}$ , based on square root of the difference of the squares calculation (IEEE802.3ae Draft 3.2, Clause 52.9.8) using 2 – 12 GHz filters (1<sup>st</sup> – O/E, 2<sup>nd</sup> – Scope)

Note 4: Resolution of measurement equipment is 0.1 nm

Note 5: Average of randomly-chosen samples



# Link Parameters (Vendor A)

## Receiver Characteristics

---

Description	Value Part 1	Value Part 2	Measured	Compliance with 802.3ae	Notes
Signal speed	10.3125 Gbps	10.3125 Gbps	Yes	Yes	
Wavelength Response	840nm (min) 860nm (max)	840nm (min) 860nm (max)	No	Yes	Note 1
Return Loss	<12 dB	<12 dB	No	Yes	Note 2
Stressed Receive Sensitivity OMA	0.100mW -10.0 dBm	0.106mW -9.7 dBm	Yes	Yes	Part 2 2 <sup>7</sup> -1 pattern



# Link Parameters (Vendor A)

## Receiver Characteristics

---

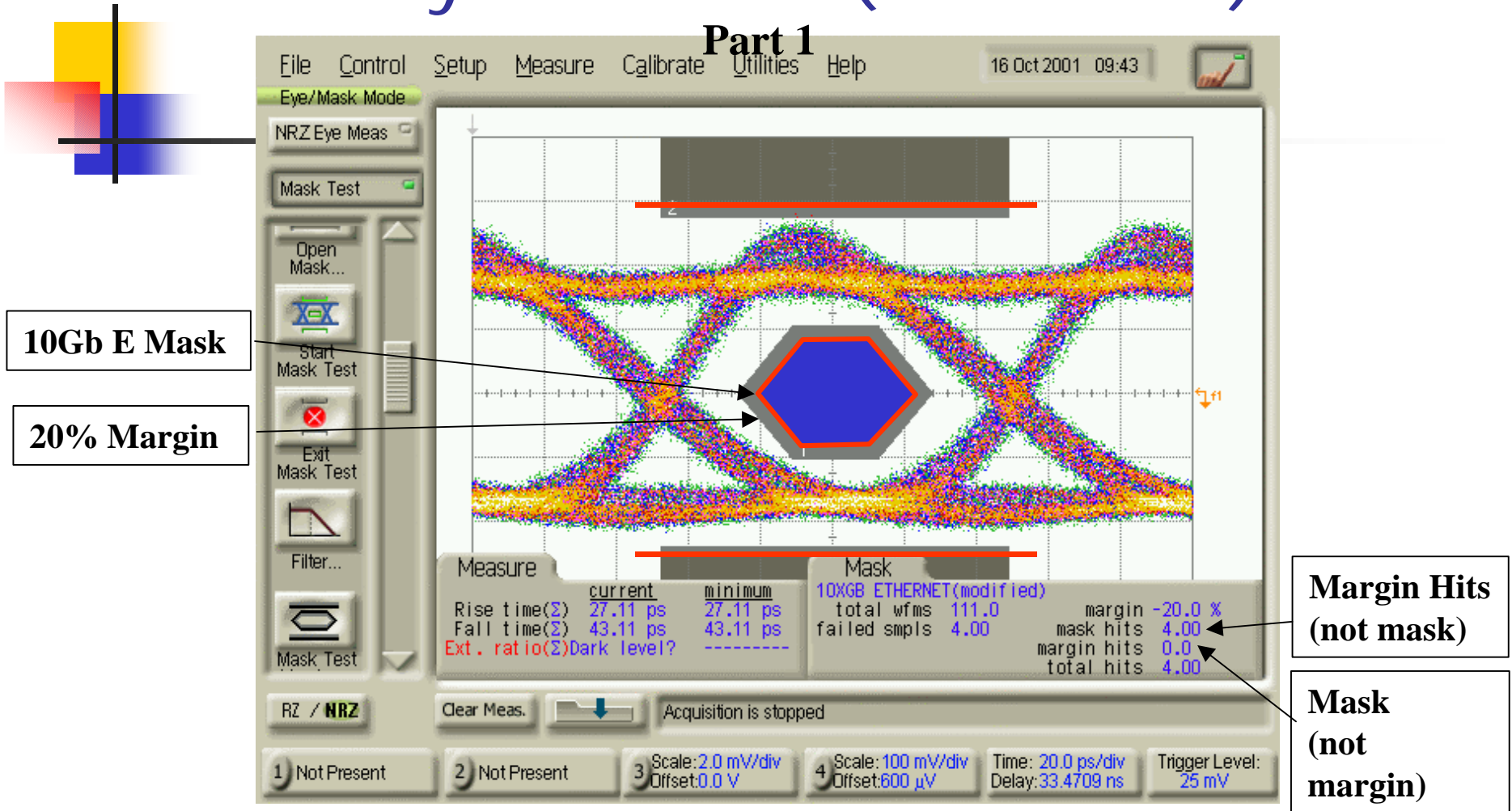
Description	Value Part 1	Value Part 2	Measured	Compliance with 802.3ae	Notes
Receive Sensitivity OMA	-13.8 dBm	-14.8 dBm	Yes	Yes	Informative
Vertical eye closure penalty	3.5 dB	3.5 dB	Yes	Yes	
Receive electrical 3 dB cutoff upper frequency	<9 GHz	<9 GHz	Yes	Yes	

Note 1: Response very predictable based on PIN Diode material

Note 2: Estimated; consistent with Gigabit Ethernet

# Tx Eye Pattern (Vendor A)

## Part 1

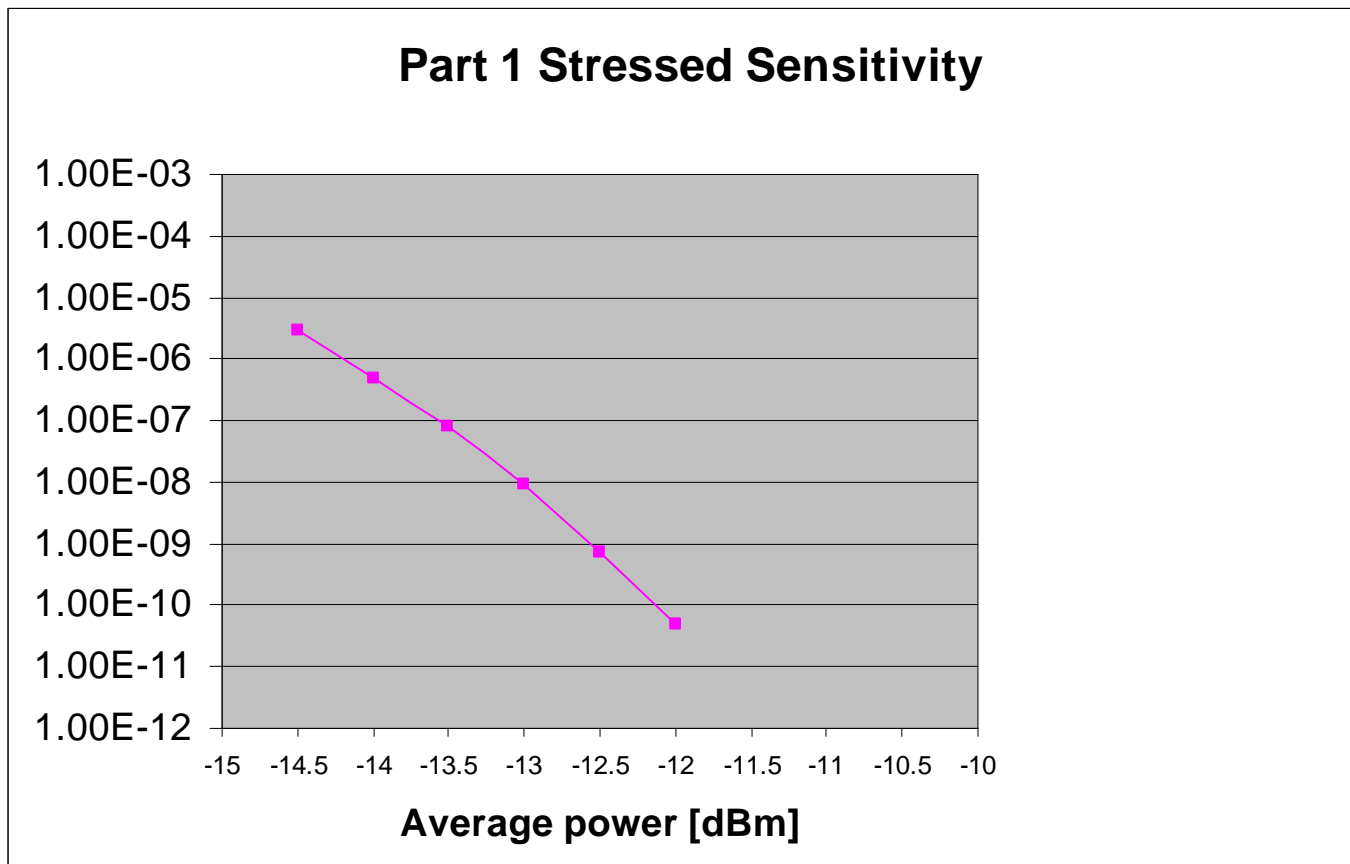


Measured extinction ratio – 7.2 dB,  $T_{fall} = 33.2\text{psec}$  (de-convolved)  
 $2^{31}-1$  PBRs data pattern w/ 2 – 12 GHz filters (1<sup>st</sup>-0/E, 2<sup>nd</sup>-Scope)



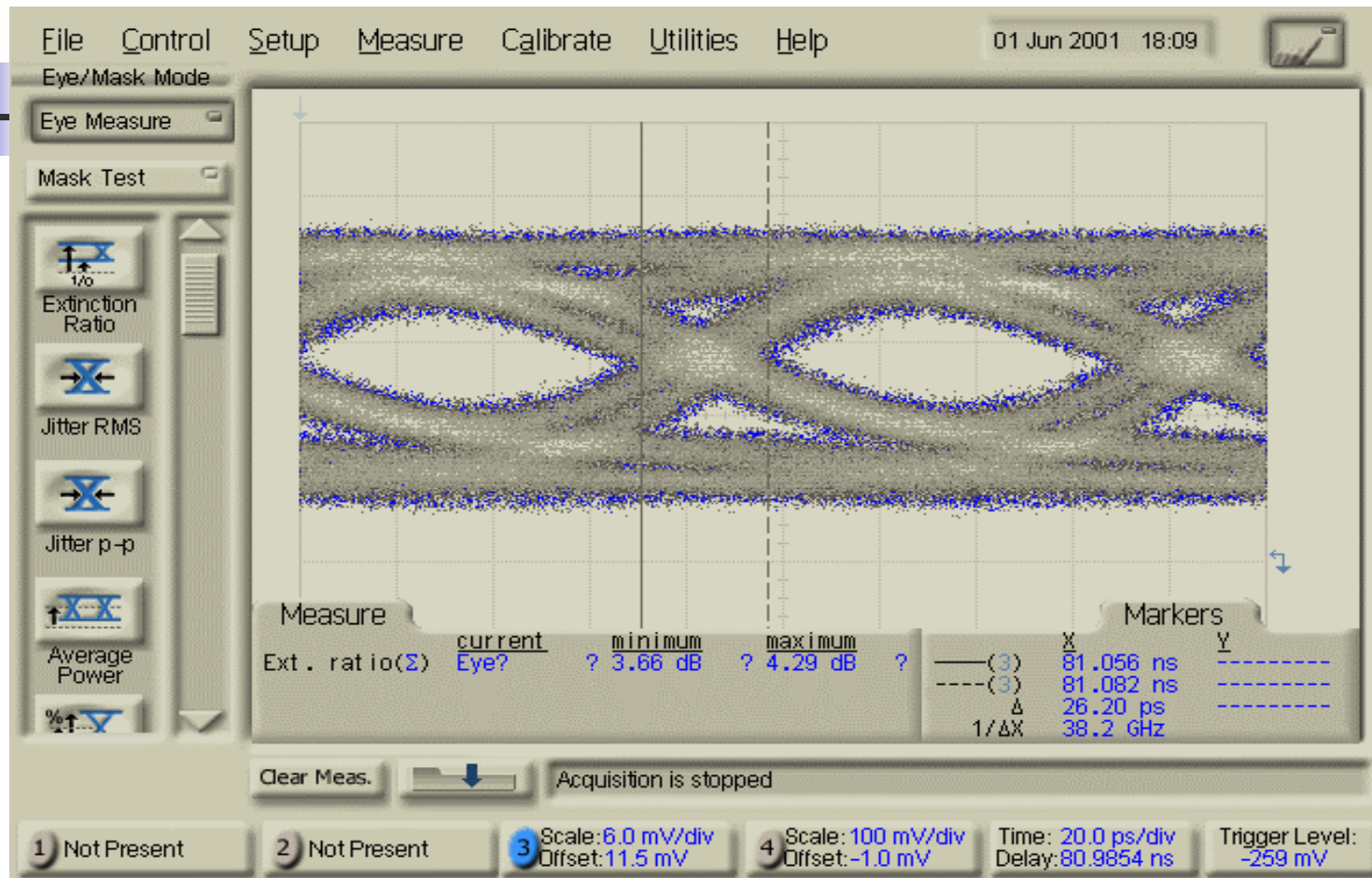
# Measured BER Curve

(Vendor A)



# Stressed Receive Input

(Vendor A) Reference Tx



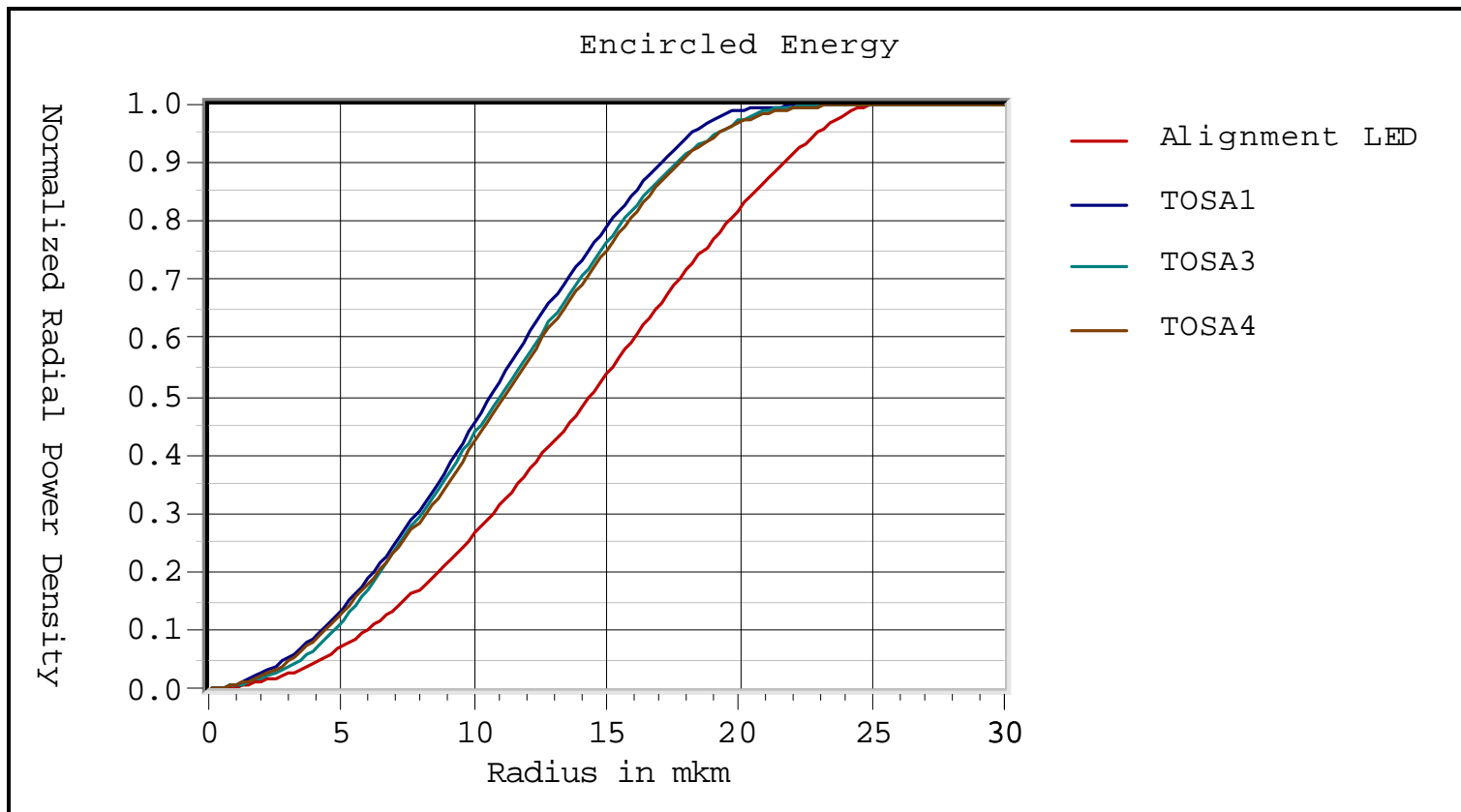
Stressed eye as measured with the 7.6 GHz Golden receiver.

p-p closure = 3.2 dB,. Peak closure = 3.5 dB

# Encircled Flux Measurement

(Vendor A)

Random Tx OSA DUTs





# Path to compliance

(Vendor A)

---

## Vendor A $\Rightarrow$ Critical Performance Issues

- Nearly complete set of data taken from each of two modules
- Path: Verification of compliance through complete testing of production volumes



# Vendor B performance data

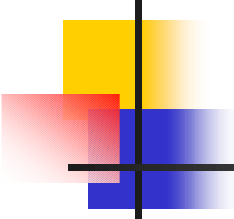
---

# Link Parameters (Vendor B)

Specification	Value Part 1	802.3ae 10GBASE-S Value	Units	Compliance	Notes
Signal Speed	10.3125	<b>10.3125</b>	GBd	Yes	
<b>TRANSMITTER</b>					
Wavelength	843	<b>ttc</b>	nm	-	ttc = triple trade-off curve
RMS spectral width	0.59	<b>ttc</b>	nm	-	ttc = triple trade-off curve
Launch power in OMA	-1.3	<b>ttc</b>	dBm	-	ttc = triple trade-off curve
Triple trade-off curve				No	Spectral width not on curve
Trise/Tfall	54.5 (fall)	<b>35</b>	ps	No	

# Link Parameters (Vendor B) continued

Transmitter (cont.)	Value Part 1	802.3ae 10GBASE-S Value	Units	Compliance	Notes
Ave. Launch power	-1.3	<b>-1.3</b>	dBm	Yes	Eye safe limit = -1.3 dBm
Extinction ratio	3	<b>3</b>	dB	Yes	
RIN <sub>12</sub> OMA	Not measured	<b>-125 dB/Hz</b>	dB/Hz	-	
Encircled flux	Data not available	<b>19 mm &gt;86%</b> <b>4.5 mm = &lt;30%</b>		Yes	
<b>Fiber Link</b>					
Fiber Attenuation	Not measured	<b>3.5</b>	dB/km	-	Assume 3.5 dB/km
Connector Loss	Not measured	<b>1.5</b>	dB	-	Assume 1.5 dB
<b>Receiver</b>					
Stressed Rx sensitivity	-4.8	<b>-7.08</b>	dBm	No	Estimated



# Path to compliance (Vendor B)

---

- Vendor B  $\Rightarrow$  Critical Performance Issues
- Through improvements to IC's and tweaks to laser Transponder B module will be brought into compliance





# Other 10GBASE-S performance demonstrations

---

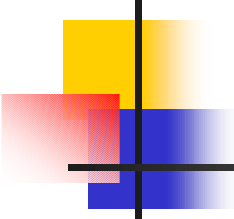
- OFC 2000, March 2001, Baltimore, MD
- IEEE Interim Meeting, Sep 2000, New Orleans, LA
- NFOEC 2000, Denver, CO
- N+I 2001, Sep 2001, Atlanta, GA
  - System interoperability demonstration @ 10GEA booth
  - 10GBASE-SW & SR links with XSBI and XAUI based modules
- ECOC 2001, Sep 2001, Amsterdam
  - IBM reported 20 Gbit/s link using VCSELs and SiGe driver (r.t. 20 ps, DJ = 11ps)



# 10GBASE-S is Technically Feasible Because....

---

- Successfully interoperated between two 10GBASE-S module vendors with 150% link distance, 450 m over the least margined fiber type (2000 MHz-km standard fiber).
- Vendor A demonstrated compliance on all measured parameters
- Vendor B demonstrated credible path to compliance
- Compliance or path to compliance were described via a comparison of measured vs IEEE required link parameters



# 10GBASE-S is Technically Feasible Because....

---

- Multiple vendors exist (2 demonstrated)
  - Picolight
  - Cielo
- Two other vendors plan to support 10GBASE-S
  - IBM
  - Stratos Lightwave

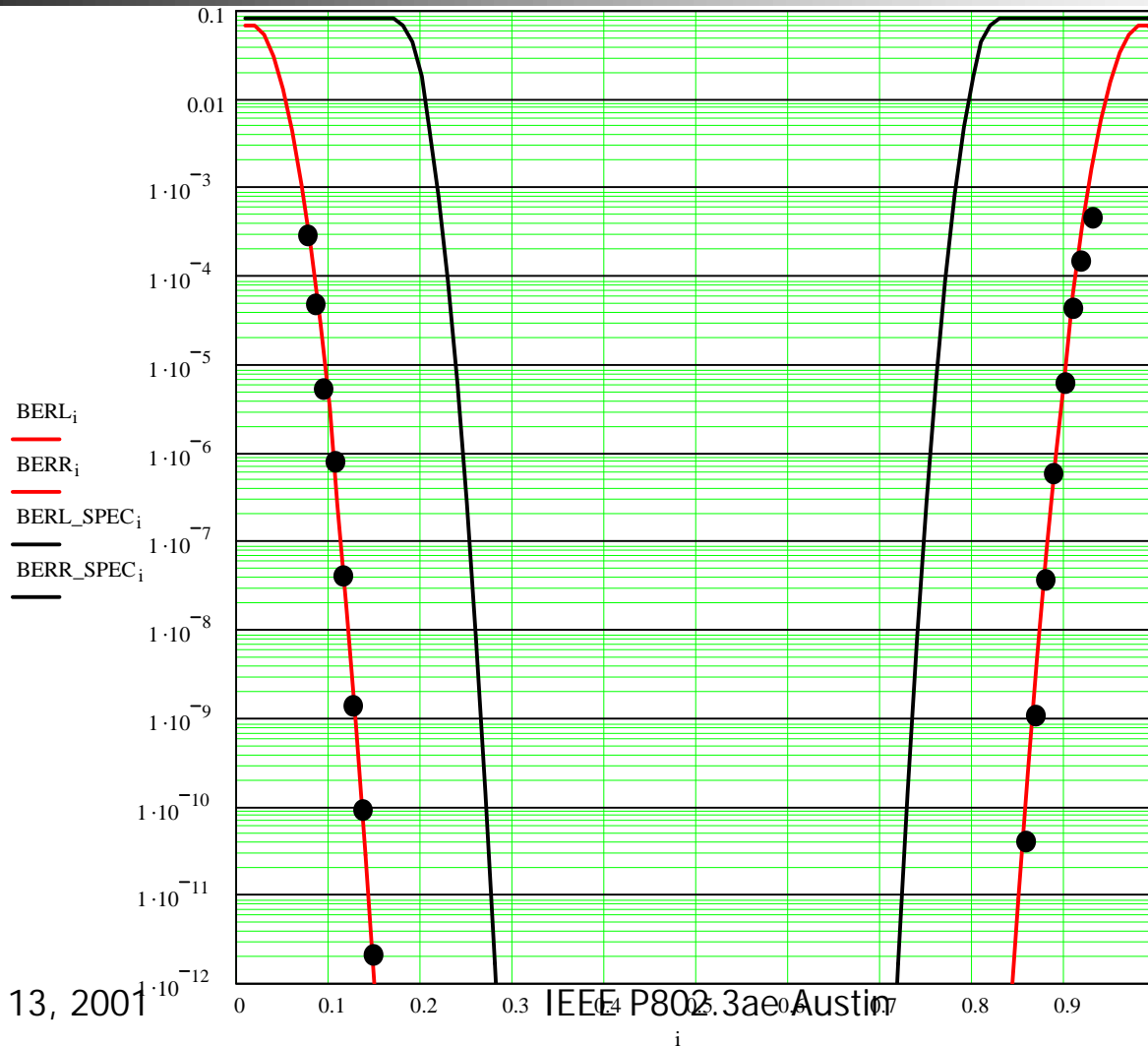


# Clause 52 Progress since LA meeting

---

- Strawpoll indicated strong support for Technical Feasibility of 10GBASE-S (no negative votes)
- One area all PMDs were asked to address is measurement technique validation
  - In particular, bathtubs were brought up (across all clauses)

# Picolight transmit bathtub



Nov 13, 2001

IEEE P802.3ae Austin



# Conclusion

---

- 10GBASE-S is technically feasible
  - Link operates at BER of  $<10^{-12}$  over all specified link distances/fiber types
  - Multiple vendors creating products for 10GBASE-S PMDs
  - All required subcomponents available
  - All vendors agree that parameters in D3.3 are reasonable and achievable (no changes required)