Proposal for 1310nm 40GbE SMF PMD

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Introduction

- One of the key decisions for the 40GbE SMF PMD specification is selection of the transmitter operating wavelength range: 1310nm vs. 1550nm, as pointed out in anslow_02_0110 (New Orleans SG meeting, Jan. 2010)

- This contribution proposes the 1310nm tx operating wavelength range be selected and is presented in the following parts:

  1. Comparison of 1310nm vs. 1550nm optics solutions and transceiver trends;

  2. Demonstration of 1310nm solution in meeting P802.3bg objectives;

  3. Proposal on 1310nm optical characteristics and link budget for P802.3bg.

Supporters

- H. Aruga – Mitsubishi
- H. Horikawa – Oki Semiconductor
- O. Ishida – NTT Labs
- Z. Li - Huawei Technologies
- H. Takahashi – KDDI Labs

Part 1 - Outline

1. Summary of 1310nm vs. 1550nm solutions
2. Details of 1310nm vs 1550nm optics comparison
3. 40G Transceiver form factor trend
4. 40G Transceiver relative cost trend

1310nm vs. 1550nm Comparison Summary

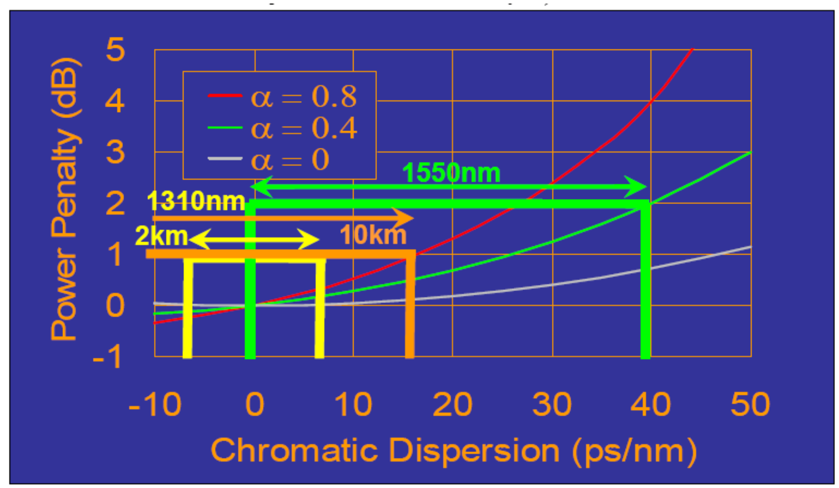
1310nm Solution	1550nm Solution
Pros ▪ Provides 10km reach with negligible added cost over 2km reach ▪ Lower cost TOSA due to easier dispersion control ▪ Multiple EML suppliers ▪ Path to uncooled EML devices and DML technology ▪ Roadmap to smaller form factor QSFP transceiver modules ▪ Can leverage greater 40GE-LR volume for significantly reducing transceiver IC component cost ***Cons*** ▪ Non-interopt w/ estimated 25% of legacy VSR2000-3R2 transceivers* ▪ Test plug-in needs to be developed	***Pros*** ▪ Backwards compatibility with legacy VSR2000-3R2 transceivers ▪ Test equipment plug-in already exits ▪ Multiple EML suppliers ***Cons*** ▪ Reach is dispersion limited to 2km ▪ Dispersion control cost penalty ▪ No path to uncooled EML or DML devices ▪ No roadmap to smaller form factor transceiver modules ▪ Only addresses relatively small 40G VSR demand volume; difficult to achieve significant transceiver cost reduction

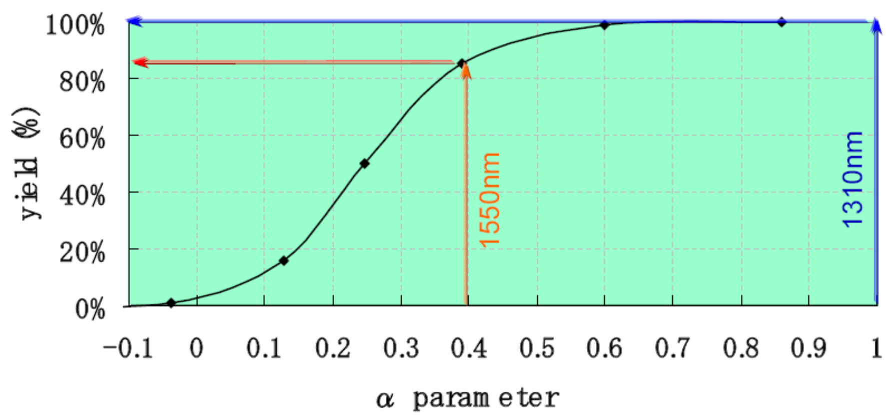
* Ref: anslow_01_0510

Comparison of 1310nm vs. 1550nm 40G EML (1)

Key differentiation is control of Chromatic Dispersion (CD) and chirp parameter (α)

- CD at 1310nm is nearly negligible compared to 1550nm on SMF
- For 2km link, chirp parameter (α):
  - required to be screened for α < 0.4 for 1550nm EML
  - does not need to be tested for 1310nm EML.
- For 10km link, α is more tolerable for 1310nm EML than in 2 km link for 1550nm EML
- Opnext estimates 1550nm EML chip/TOSA yield loss due to chirp screening is 15%
- Chirp testing and yield loss results in ~25% higher 1550 EML TOSA cost over 1310nm EML TOSA

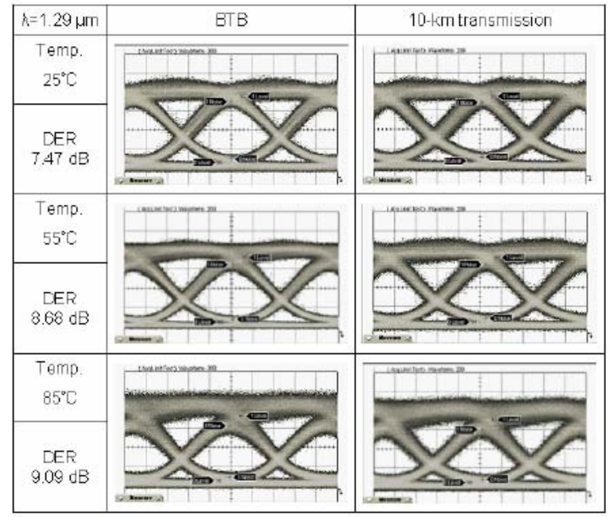




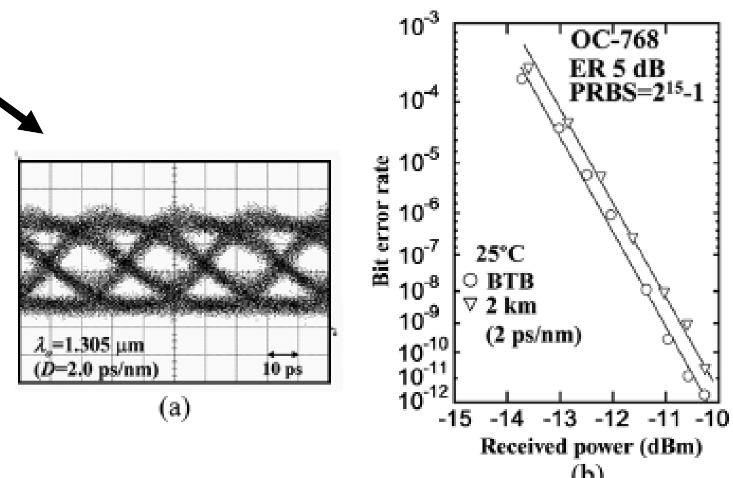
Source: Opnext

Comparison of 1310nm vs. 1550nm 40G EML (2)

- 1310nm provides an easier path than 1550nm to uncooled, wide operating temperature range EML devices:
  - Easier wavelength detuning ($\Delta\lambda_{DFB-EA}$) optimization across temperature range;
  - Easier freq BW-ER optimization
- Opnext/Hitachi CRL work has demonstrated feasibility of uncooled 43 Gb/s EML laser devices
- 40G 1310nm DML device technology development in progress
- *Uncooled EML and cooled DML devices on the horizon and are critical for realizing lower cost, smaller form factor 40G transceivers*



Ref: H. Hayashi, et al. ECOC 2008, We3.C.3



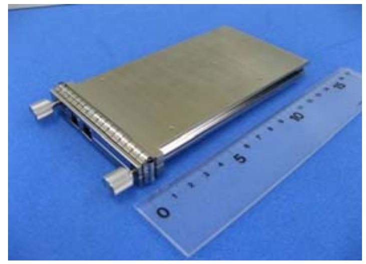
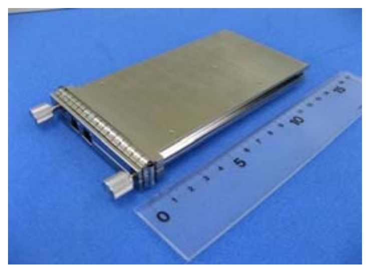
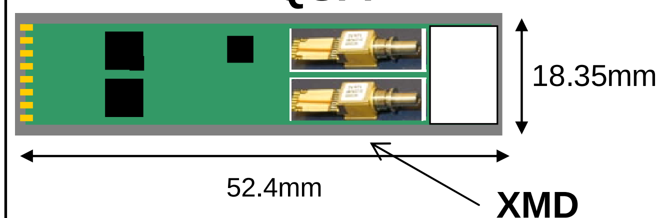
Ref: K. Nakahara et al., IEEE PTL, vol. 19, pgs. 1436-1438 (Oct. 2007)

40G EML Optics Comparison Summary

	1310nm Solution (proposed for P802.3bg)	1550nm Solution (ITU-T G.693 VSR2000-3R2)
Output Power	**2 ~ 3 dB advantage, allowing greater link budget**	
Chromatic Dispersion	$\leq \pm 16$ ps/nm	**~ 40 ps/nm**
EML TOSA Power Consumption	**Path to uncooled device, eliminates TEC, reducing Pc over 50% (~ 1W)***	**No immediate path to uncooled device** **TEC required; higher power**
EML TOSA size	**Smaller, receptacle-type form factors, e.g. TO-CAN, easier to realize***	**Difficult to reduce package size**
EML chip/TOSA cost	- **No chirp testing, yield loss** - **Uncooled device eliminates TEC and associated circuitry,** - **Reduces packaging cost** - **50-75% lower cost may be realized***	- **Chip/TOSA chirp testing, yield loss increases cost;** - **higher cost with TEC and bias control circuitry for dispersion control**

* Based on 10G ER cooled and uncooled EA-DFB TOSA design experience

40G serial client module roadmap

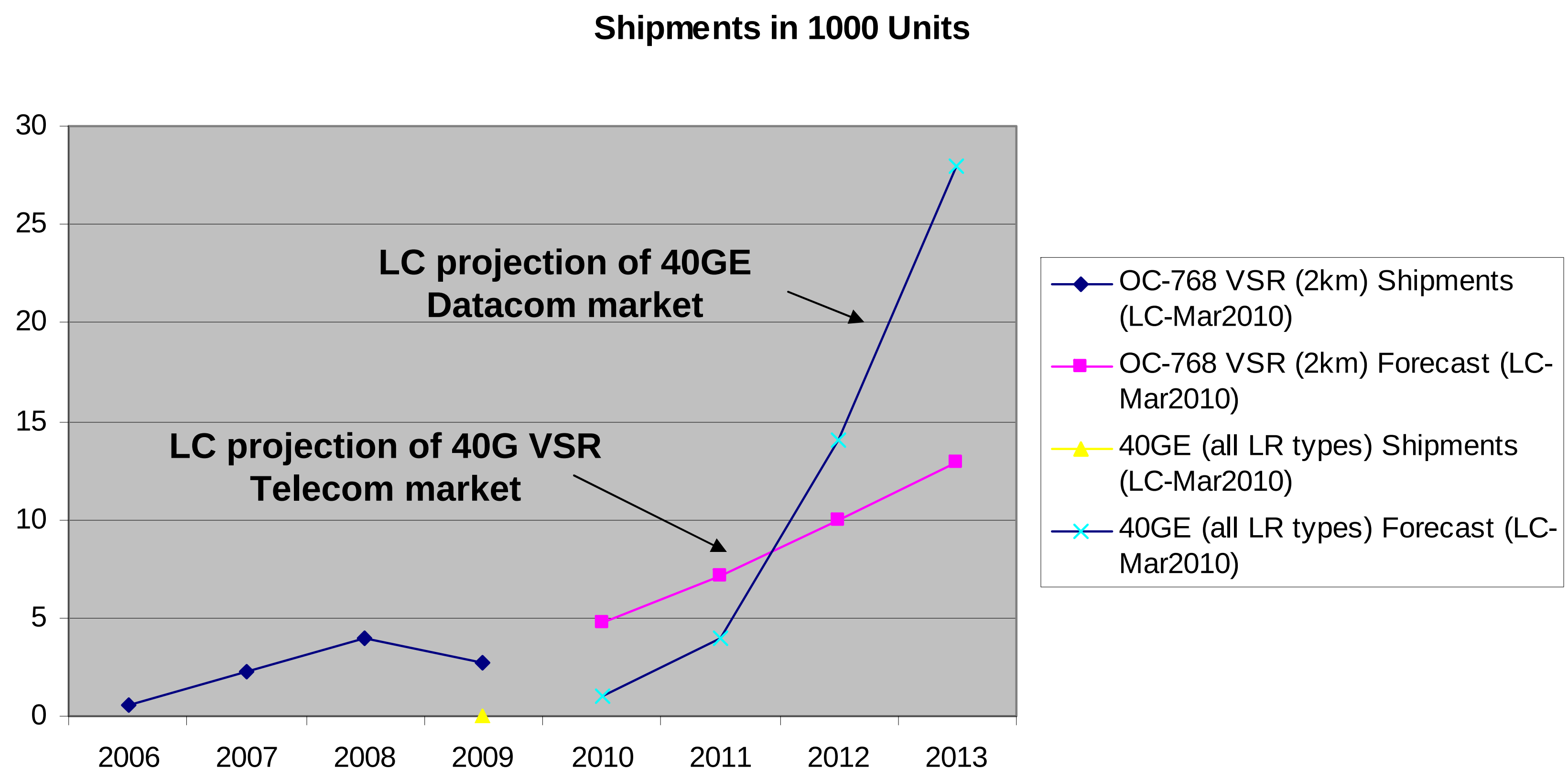
		Current	Next Gen	Future
1550nm	FF	 3.5" x 4.5" SFF	 3.2" x 5.7" CFP	??
	Pc	12 -15W	8 -10W	Pc > 5.5W
1310nm	FF	NA	 3.2" x 5.7" CFP	QSFP  Possible!
	Pc		8 -10W	3.5 – 4.4 W Using uncooled EML & Serdes w/ optimized deskew

40G serial client module power comparison

Component	1550nm 40G 2km			1310nm 40G 10km	
	Current Gen SFF Power* (W)	Next Gen CFP Power** (W)	Future FF?? Power** (W)	1st Gen CFP Power** (W)	Future QSFP Power** (W)
EML TOSA	1.5 (cooled)	1.5 (cooled)	1.5 (cooled)	1.5 (cooled)	0.5 (uncooled)
EML Driver	1.5	1.2	0.8	1.2	0.8
PD/TIA	1.3	1.0	0.4	1.0	0.4
4:1 / 1:4 SerDes	6 - 8	2.5 – 4 1-chip	2.5 – 4 1-chip	2.5 – 4 1-chip	1.5 – 2.2 2nd gen IC w/ optimized deskew
Misc	2 - 3	1.5 - 2	0.3 – 0.5	1.5 - 2	0.3 – 0.5
Total Pc	12 - 15	8 - 10	5.5 - 7	8 - 10	3.5 – 4.4

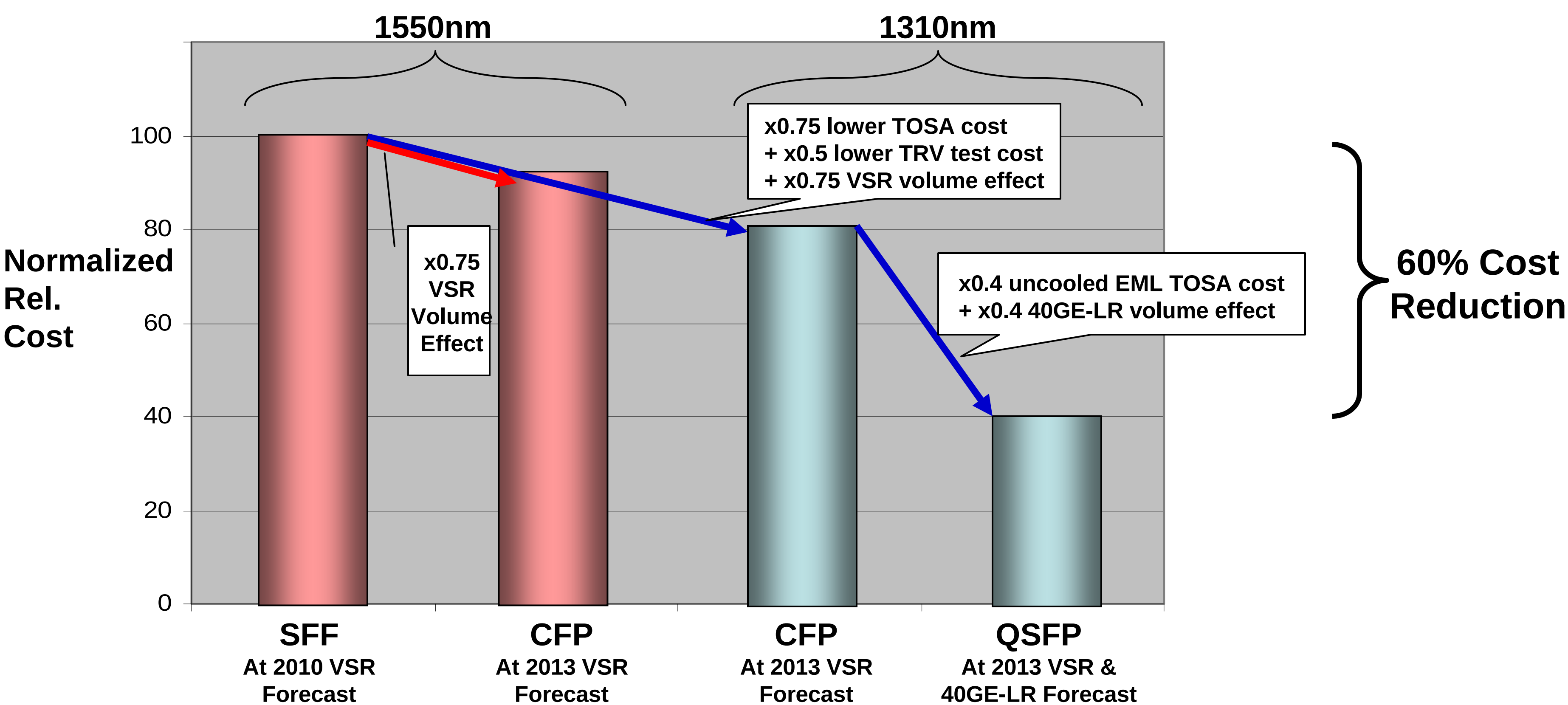
* Measured ** Design estimates based on 10G ER, 100G-LR4 design experience and IC supplier input

Market Analysis Update: Historical and Projected 40G Unit Volume



Unit volumes are from LightCounting (LC) March, 2010 Report.
LC projections use a mathematical model developed by LightCounting.

40G Transceiver Relative Cost Trend



- **Cost model includes TOSA, driver, PD/TIA ROSA, SerDes IC, TRV package, assembly & test**
- **1310nm TOSA cost reduction realized by (1) eliminated chirp test & yield loss, (2) uncooled EML**
- **SerDes + other pkg cost reduction for 1310nm realized by 40GE LR volume effect, assumed QSFP volume is 2x VSR volume in 2013 with increasing LR volume share future outlook**
- **1550nm solution cannot address LR market, thus cannot realize increased volume cost reduction**

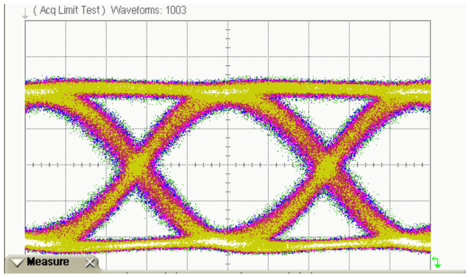
Part 2 – Demonstration of 1310nm solution

- This section presents interoperability test results of Opnext 40G 1310nm EML transmitter with an Opnext 40G 300pin LFF VSR2000-3R2 transceiver over 2km and 10km SMF links.

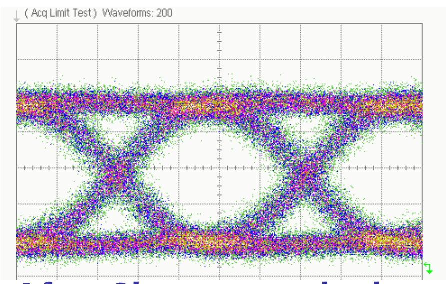
- Additional test results from 40G 1310nm EML device suppliers demonstrating 10km and 40km reach feasibility are provided in annex of this presentation.

Opnext 40G 1310nm EML Transmission by XMD-like TOSA

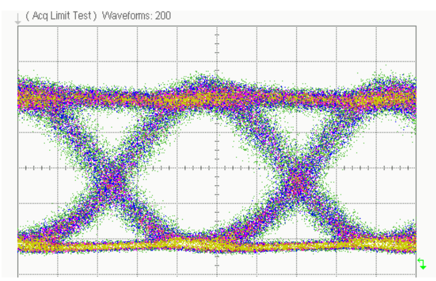
39.8 Gbit/s Optical waveforms



BTB, Pave=+4.7dBm, Er=10dB



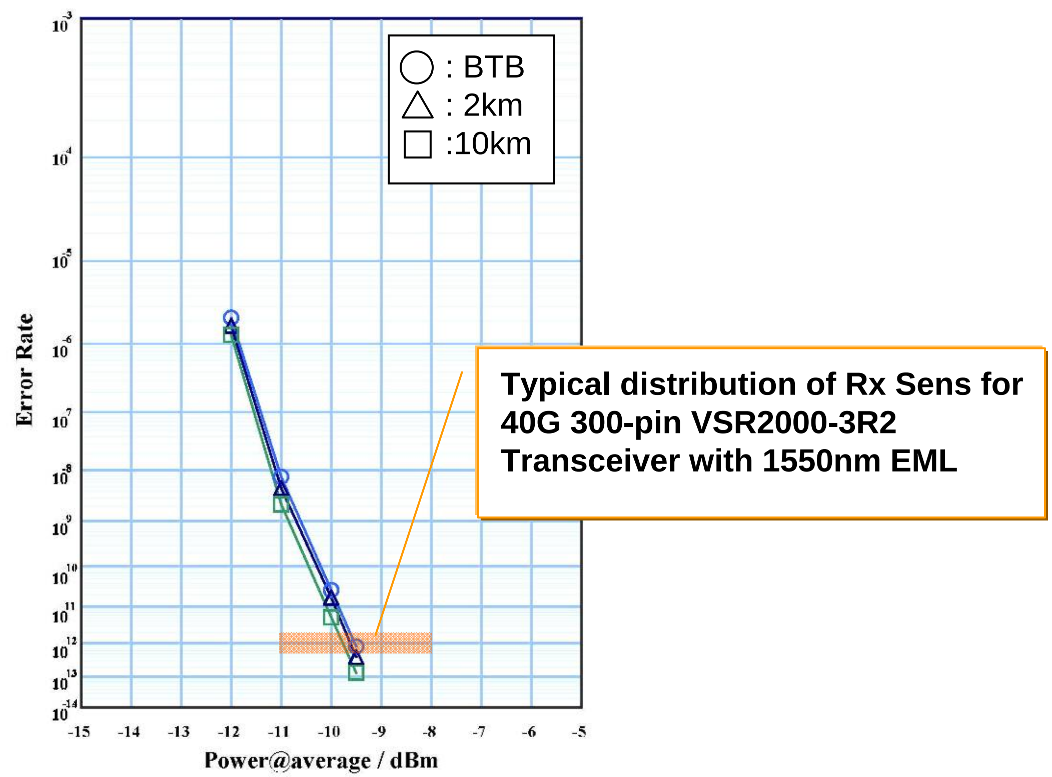
After 2km transmission



After 10km transmission

39.8 Gbit/s BER-characteristics, PRBS 2^{31}-1, Room temp.

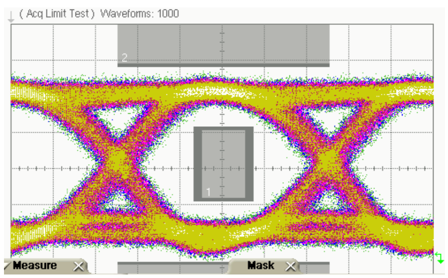
Tx: 1310nm EML + Driver IC
Rx: 40G 300-pin VSR2000-3R2 Transceiver



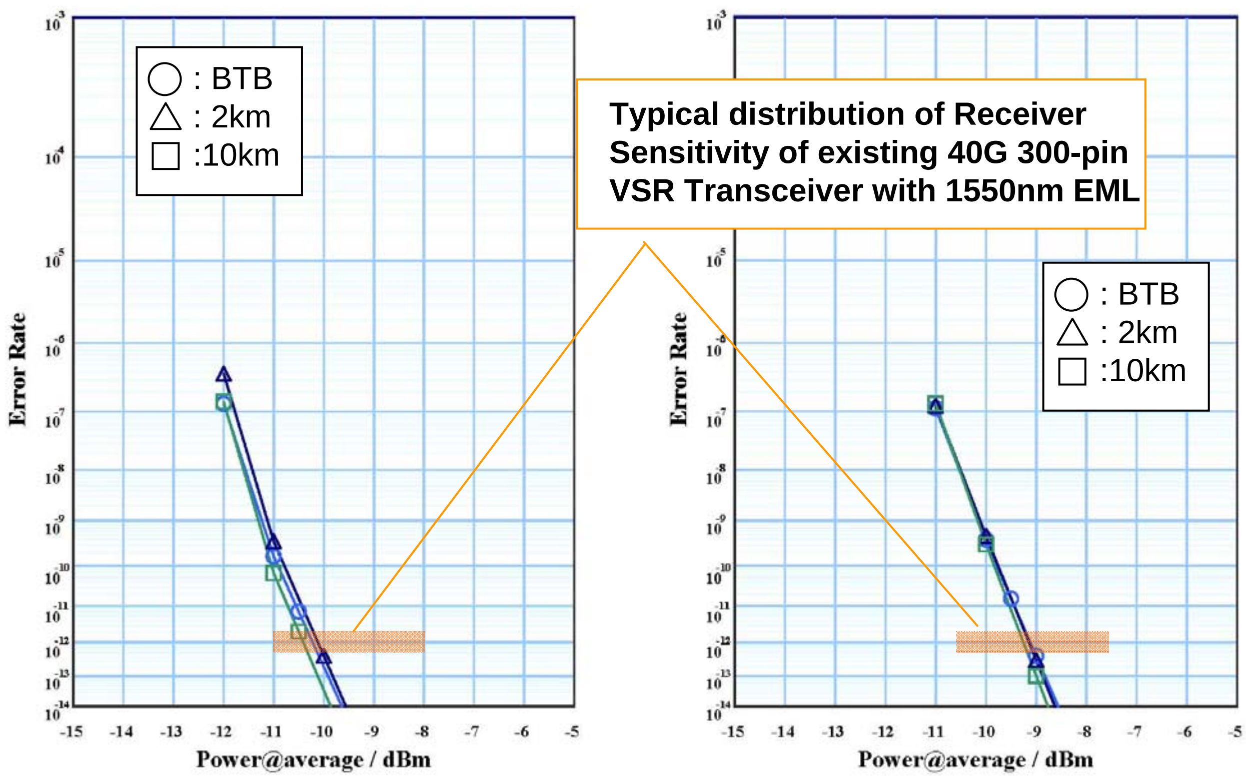
Opnext 40G 1310nm EML Transmission by XLMD TOSA

Tx: 40G 300-pin VSR Transceiver with 1310nm XLMD TOSA
Rx: 40G 300-pin VSR2000-3R2 Transceiver

39.8 Gbit/s
Optical waveforms



BTB, Pave=+3.8dBm,
Er=9.6dB, MM > 10%



39.8 Gbit/s, PRBS 2^{31}-1, Room temp. **43.0 Gbit/s PRBS 2^{31}-1, Room temp.**

Part 2 – Summary

- A 1310nm PMD solution which supports 40Gb/s operation over at least 2 km on SMF has been demonstrated.
- Optical compatibility of a 1310nm PMD solution with an existing 40Gb/s VSR2000-3R2 interface over 2km SMF has been demonstrated.
- Feasibility of extending the 1310nm PMD solution to 10km on SMF has been demonstrated.

Part 3 – 1310nm Optical Link Budget Proposal

- It is proposed the existing optical power budget and specs given in ITU-T G959.1 for application code P1I1-3D1 (10km) and per anslow_03_0510 be adopted for specifying the 1310nm 40GBASE-LR SMF PMD.

Proposed 1310nm Transmit Characteristics

Description	Value	Unit
Signaling rate (range)	41.25 ± 100 ppm	GBd
Center wavelength (range)	1307 to 1317	nm
Side-mode suppression ratio (SMSR), (min)	35	dB
Average launch power (max)	3	dBm
Average launch power (min)	0	dBm
Dispersion penalty (max)	1	dB
Average launch power of OFF transmitter (max)	–30	dBm
Extinction ratio (min)	8.2	dB
$RIN_{20}OMA$ (max)	TBD	dB/Hz
Optical return loss tolerance (max)	20	dB
Transmitter reflectance[a] (max)	–12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{TBD}	

[a]Transmitter reflectance is defined looking into the transmitter.

Proposed 1310nm Receive Characteristics

Description	Value	Unit
Signaling rate (range)	41.25 ± 100 ppm	GBd
Center wavelength (range)	1307 to 1317 and 1530 to 1565	nm
Damage threshold[a] (min)	4	dBm
Average receive power (max)	3	dBm
Receiver reflectance (max)	−26	dB
Receiver sensitivity (average power) (max)	−7	dBm
Receiver jitter tolerance BER limit (max)	10^{-12}	—
Receiver 3 dB electrical upper cutoff frequency, each lane (max)	49	GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level

Proposed 1310nm 10km Optical Link Budget

Parameter	Value	Unit
Power budget	7	dB
Operating distance	10	km
Channel insertion loss[a]	6	dB
Maximum discrete reflectance	–26	dB
Allocation for penalties[b]	1	dB
Additional insertion loss allowed	0	dB

[a]The channel insertion loss is calculated using the maximum distance specified in Table 89–5 and cabled optical fiber attenuation of TBD dB/km at TBD nm plus an allocation for connection and splice loss given in 89.10.2.1.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Conclusion

- This contribution:
  - Identified key advantages of selecting 1310nm operating wavelength range over 1550nm for specifying the 40GE SMF PMD;
  - Demonstrated that P802.3bg reach and optical compatibility objectives can be meet with a 1310nm transmit solution.
  - Proposed 1310nm optical transmit/receive characteristics and a 10km link budget for P802.3bg.
- It is proposed the 1310nm solution described herein be adopted for P802.3bg.

Annex

- Additional test results from 40G 1310nm EML device suppliers demonstrating 10km and 40km reach feasibility.

Mitsubishi 40G 1310nm EML Transmission

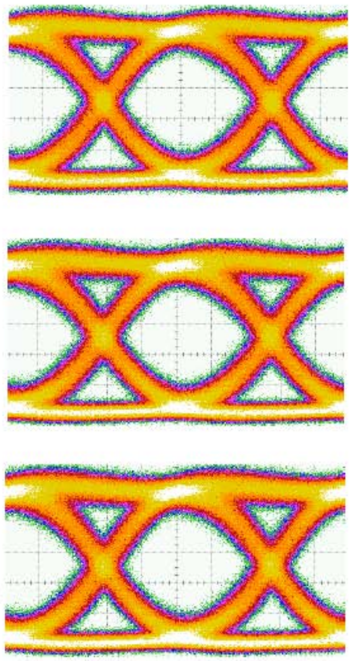
10 / 40 km Transmission Experiments
→ No degradation in optical waveforms
→ Low power penalty < 0.3 dB

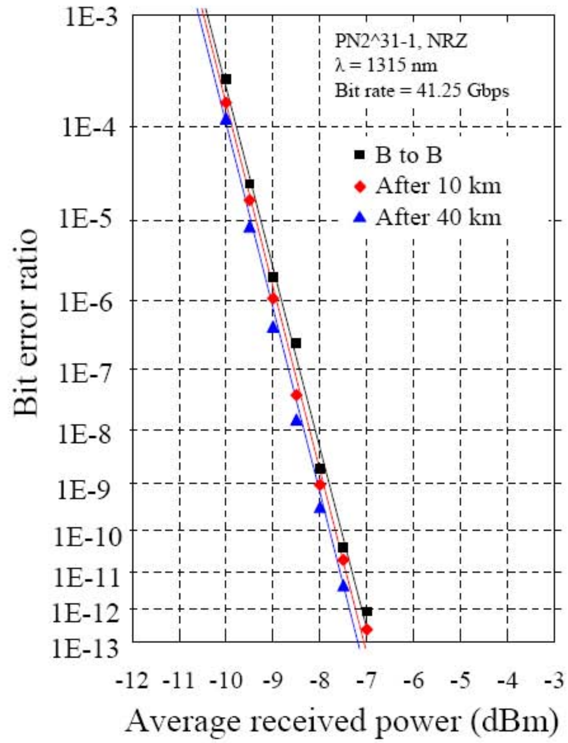
41.25 Gbps Optical Waveforms
(1000 waveforms integration)

B to B

SMF 10 km
(-1.98 ps / nm)

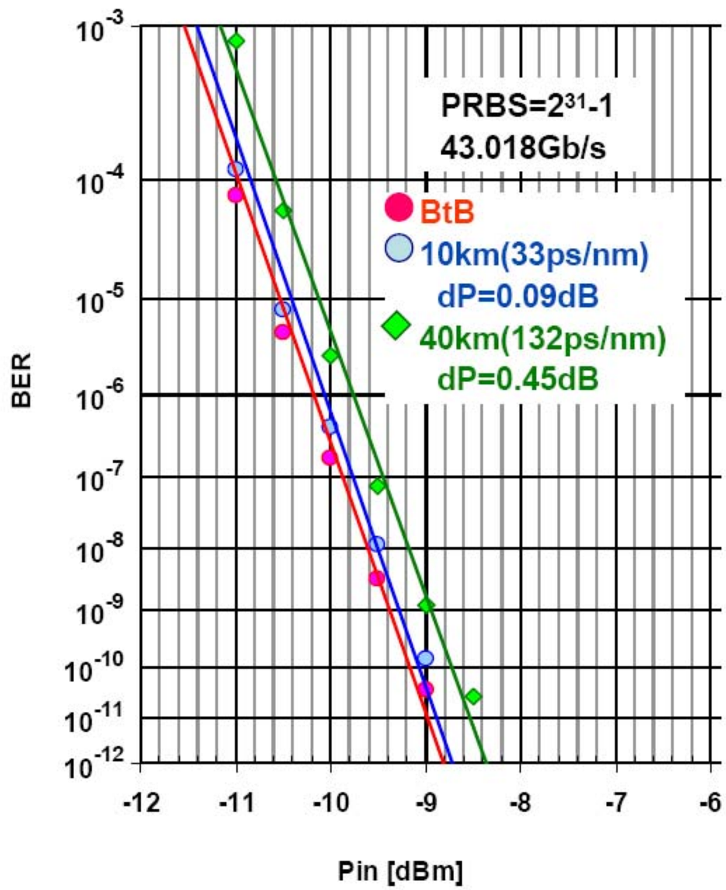
SMF 40 km
(-12.76 ps / nm)

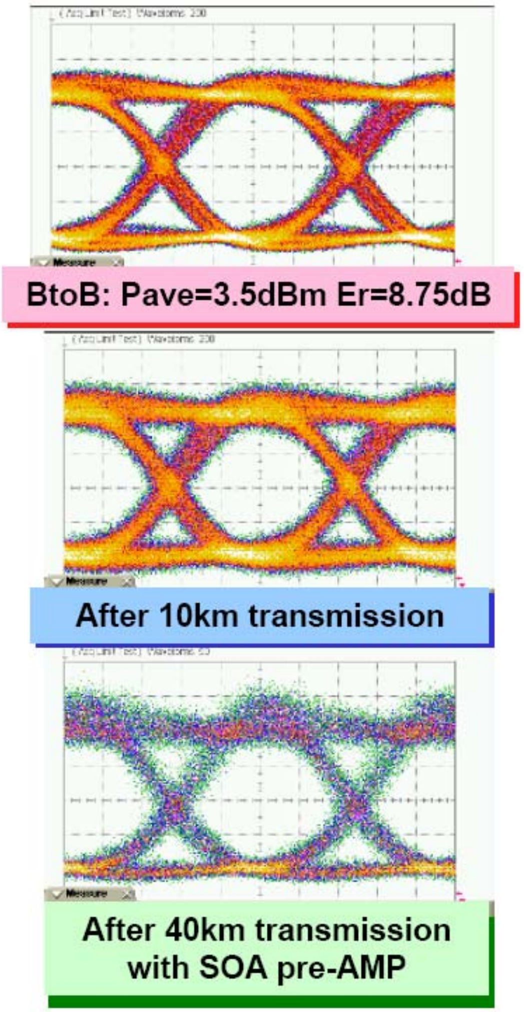




Ref: T. Uesugi, et al., OFC2010, OThC2;
Source: H. Aruga (Aruga.Hiroshi@ab.MitsubishiElectric.co.jp), 3/31/2010

Sumitomo 40G 1310nm EML Transmission

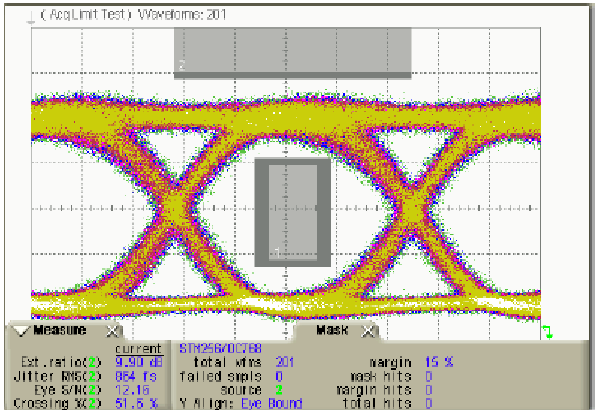




Source: H. Iwadate (HIwadate@sei-device.com), 4/9/2010

OKI Semiconductor 40G 1310nm EML Transmission

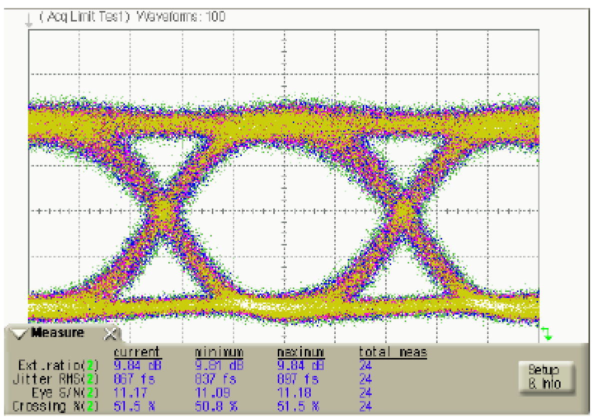
B to B



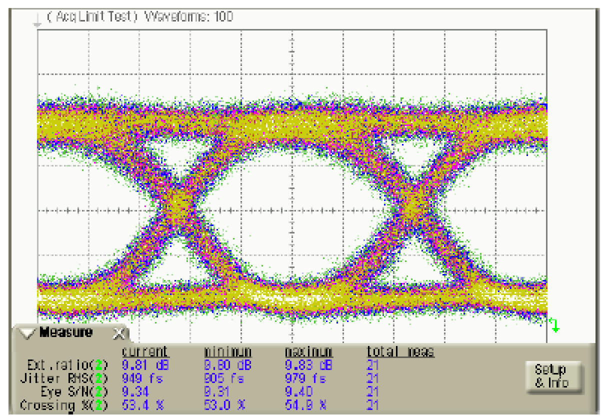
Pave=3.25dBm, ER=9.9dB

Operating Conditions:
- PRBS=2^{31}-1
- Rate: 43.018Gbps
- T_{EML}=35degC

After 2km



After 10km



Source: H. Horikawa (horikawa443@dsn.okisemi.com), 4/12/2010

End of Contribution