VCSEL Based 10 Gigabit Serial Solutions

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Jack Jewell
jljewell@picolight.com
303-530-3189

Introduction

Objectives:

1) Assess the PHY links 1, 2, 3 proposed by Vipul Bhatt

2) Modify parameters, if appropriate, to fit manufacturing capability

General Approach:

Satisfy an Aggressive/Achievable Standard

Use the Same Solution for Less Aggressive Links

Primary and Secondary Targets for 850 and 1300nm:

- ***850nm VCSEL, Enhanced MMF, 300m Reach***
  - ***850nm VCSEL, Standard MMF, 50-100m Reach***
- ***1300nm Single-Mode VCSEL, SMF, 10km Reach***
  - ***1300nm Single-Mode VCSEL, SMF, 2km Reach***

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850nm VCSEL, Standard MMF, 50-100m Reach

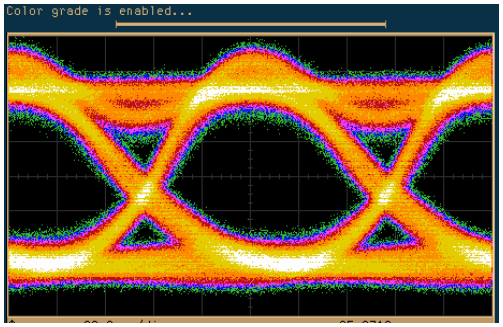
Picolight 850nm VCSELs Reach >100m Over Installed 62/125 MMF

Modeling Predicts:

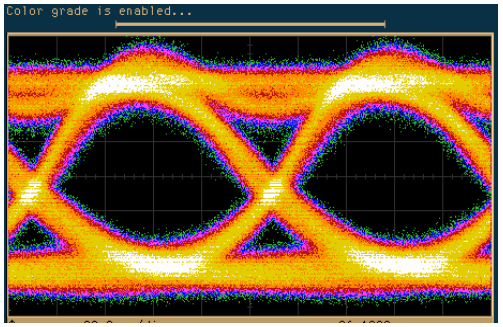
- 24m Over Worst Case Fiber (160 MHz•km)
- 55m Over Worst Case Fiber With Restricted Launch (385 MHz•km)*****
- 100m Over "Better" Installed Fiber (700 MHz•km)
- 150m Over "Still Better" Installed Fiber (1000 MHz•km)

***** TIA Restricted Launch Goal: 385 MHz•km for Worst Case Fiber

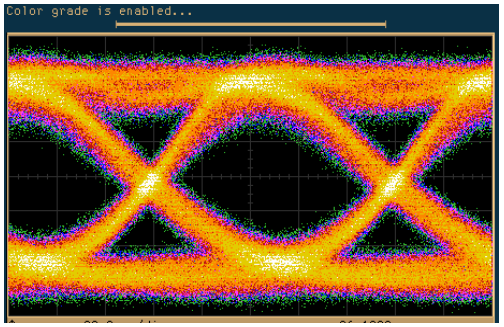
Picolight will measure encircled flux, etc. to assess requirements



2 meter 62/125 fiber



50 meter 62/125 fiber

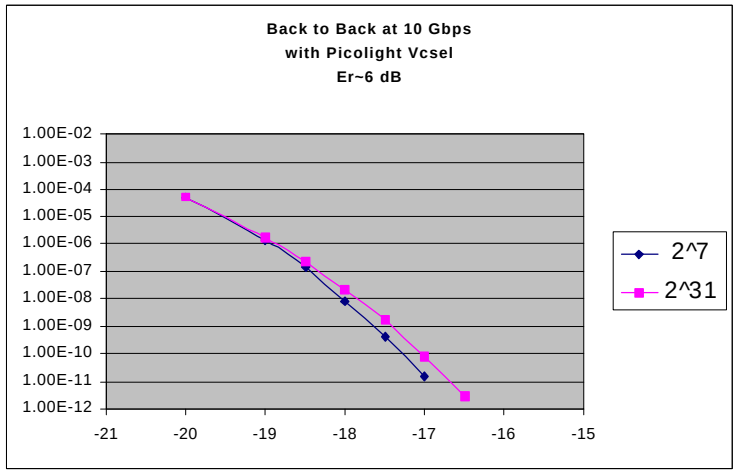


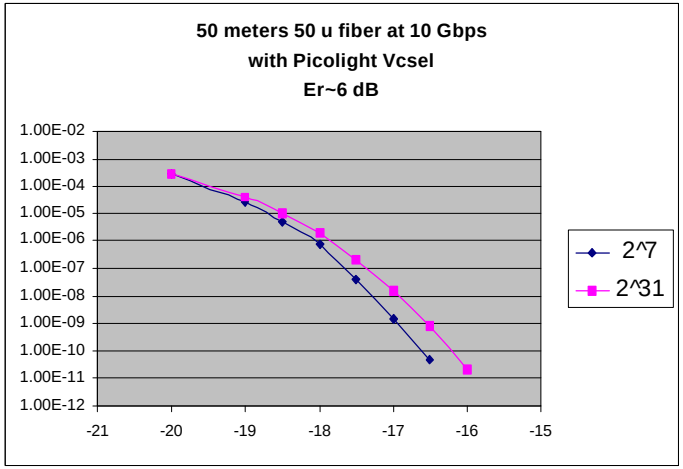
150 meter 62/125 fiber

10 Gb/s 850nm Picolight VCSEL

Back-to-Back and Through 50m of Installed 50/125 MMF

- **Little Difference Between 2^7 and 2^{31}**
- **Supports Receive Sensitivity of -15dBm**





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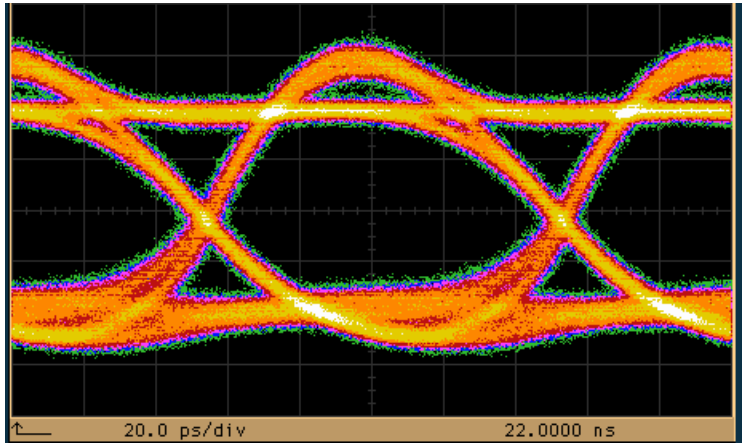
850nm VCSEL, Enhanced MMF, 300m Reach

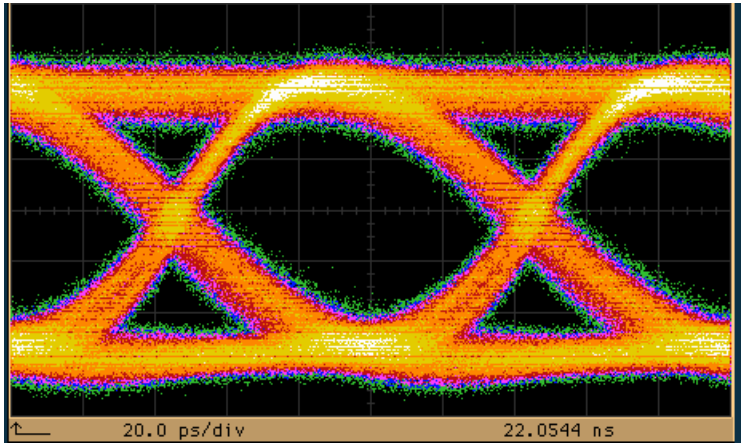
Picolight 850nm VCSELs Reach 400m Over High Bandwidth MMF

High Speed Study Group Objective: at least 300m over MMF

Modeling indicates ~300m for 'controlled launch' of new high BW fibers



Back-to-back fiber

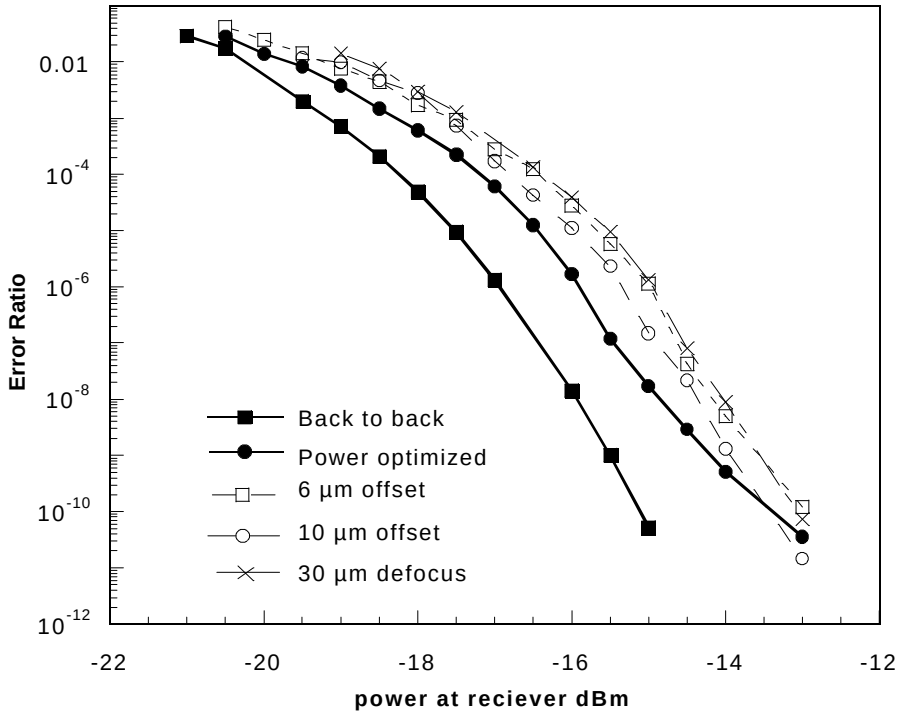


400 meter Lucent LazrSPEED™ fiber

Alignment Sensitivity

Picolight 850nm VCSEL Through 400m LazrSPEED™ MMF

±10μm Lateral Misalignment → No Large Penalty,
sufficient tolerance for alignment at cost <<SMF



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Reach vs Fiber Modal Bandwidth

Link Power Budget and Penalties (64B/66B) **840 nm**

Description							Units
Operating Distance	300	150	100	75	55	24	m
Fiber Modal Bandwidth	2200	1000	700	500	385	160	MHz km
Wavelength Range	840-860	840-860	840-860	840-860	840-860	840-860	nm
Link Power Budget	8	8	8	8	8	8	dB
Channel Insertion Loss	2.09	1.54	1.36	1.27	1.20	1.09	dB
Link Power Penalties	5.44	4.53	4.05	4.28	3.99	4.22	dB
Unallocated Margin	0.48	1.93	2.59	2.45	2.81	2.69	dB
Pisi	3.02	3.01	2.66	2.87	2.62	2.83	dB

Transmit Characteristics (64B/66B)

Description							Units
Signal Speed	10.312	10.312	10.312	10.312	10.312	10.312	Gbd
Wavelength Range	840-860	840-860	840-860	840-860	840-860	840-860	nm
Trise / Tfall (20%-80%)	30	30	30	30	30	30	ps
RMS Spectral Width (max)	0.40	0.40	0.40	0.40	0.40	0.40	nm
Avg Launch Power (max)	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	dBm
Avg Launch Power (min)	-7	-7	-7	-7	-7	-7	dBm
Avg Launch Power of OFF Transmitter (max)	-30	-30	-30	-30	-30	-30	dB
Extinction Ratio (min)	6	6	6	6	6	6	dB
RIN (max)	-125	-125	-125	-125	-125	-125	dB/Hz

Receive Characteristics (64B/66B)

Description							Units
Signal Speed	10.312	10.312	10.312	10.312	10.312	10.312	Gbd
Wavelength Range	840-860	840-860	840-860	840-860	840-860	840-860	nm
Avg Receive Power (max)	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	dBm
Receive Sensitivity	-15.0	-15.0	-15.0	-15.0	-15.0	-15.0	dBm
Return Loss (min)	12.00	12.00	12.00	12.00	12.00	12.00	dBm
Stressed Rx Sensitivity	-9.99	-9.44	-9.26	-9.17	-9.10	-8.99	dBm
Vertical Eye Closure Penalty	TBD	TBD	TBD	TBD	TBD	TBD	dB
Receive electrical 3dB Uper Cutoff Frequency (max)	12.36	12.36	12.36	12.36	12.36	12.36	GHz

Data Generated Via the GbE Link Simulator (With Baseline Wander)

Changes from Proposed Link Parameters for 300m Link Indicated in RED

<u>Same</u> Transmit / Receive Characteristics in All Cases

Receiver Sensitivity Under Verification

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850nm VCSEL Link Conclusions

- 850nm VCSEL Links Over 300m High Bandwidth MMF
  - >300m over fiber with 2200MHz • km works
  - Cautious optimism for such links to be robust
  - Multiple manufacturers expressing similar optimism
  - 10Gb/s circuits expected to become ubiquitous and cheap in 2001
  - Should be the lowest cost solution for links <300m
- 850nm VCSEL Links Over 55m Installed MMF
  - Model/Experiments/TIA FO-2.2 support viability with controlled launch

- The Tx / Rx spec's to meet the 300m high bandwidth fiber link will meet shorter link spec's with installed fiber
- ONLY A <u>SINGLE</u> TRANSMIT / RECEIVE SPEC NEEDED

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Longwave VCSEL Based SMF Links

1300nm Link Analysis:

1) Assess "What can VCSELs do for 1300nm Links?"

2) Use known and expected VCSEL parameters in the GbE Link Model to predict requirements/performance

3) Can VCSELs enable unification of the 2km and 10km spec's?

4) Why limit the 2km spec to a specific source having multi-mode output and narrow wavelength range? Leave door open to upcoming lower-cost solutions.

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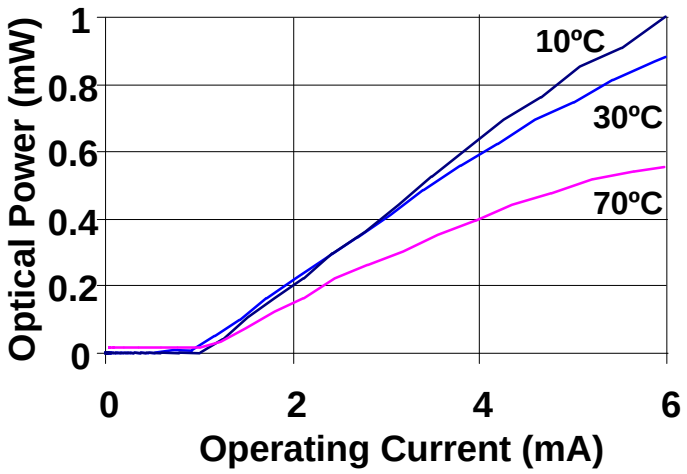
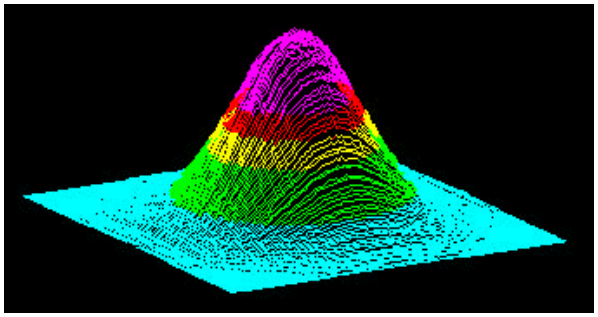
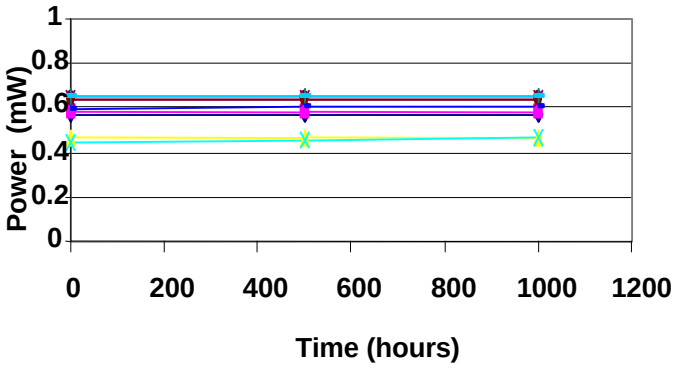
Single Transverse Mode LongWave VCSEL





Divergence (FW1/e^2) 12.3º x 13.5º

1175 nm VCSEL Reliability
Stressed at 4.5-5 mA / 70C
Measured at 4mA / 30C



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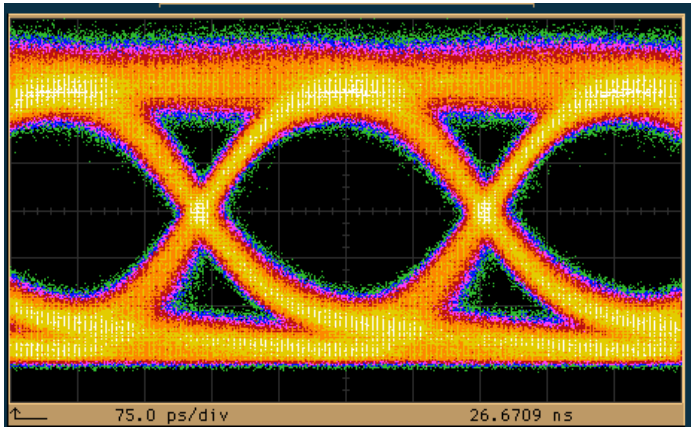
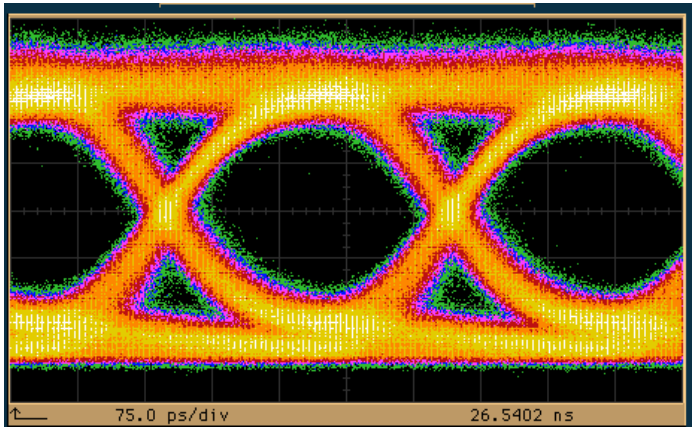
3.125 Gb/s Eye Diagrams (Filtered)

Picolight LongWave Single-Mode VCSEL Prototype (1170nm)



Back-to-Back



Through 10km of Single-Mode Fiber

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LongWave Link Simulations

Input=	**Bold**						
		BWm(MHz*km)=	**1000000**		L_start (km)=	**0.1**	
Uc(nm)=	**1260**	So(ps/nm^2*km)=	**0.093**		L_inc (km)=	**0.01**	
Uw(nm)=	**0.30**	Uo(nm)=	**1324**		C1=	**480**	ns/MHz
Spec ER=	**6** dB	Atten=	**0.5**	dB/km	Q=	**7.00**	
Ts(20-80)=	**0.03** ns	se Rate=	**10312**	MBd	TP4 Eye Opening=	**24**	ps
RIN=	**-130** dB/Hz	ec_BW=	**8000**	MHz	DCD_DJ(ps)=	**10**	
MPN, k=	**0**	ower Budget P (dB)=	**11**		Min Launch Pwr(dBm)=	**-6.0**	
MN (dB)=	**0**	Connections C (dB)=	**2**		Test Source ER (dB)=	**7**	
					RMS Baseline wander S.D.=	**0.025**	fraction of 1/2 eye

Transmit Characteristics (64B/66B)

Description	10km	2km	0.6km	Units
Signal Speed	10.312	10.312	10.312	Gbd
Wavelength Range	1.26-1.35	1.26-1.35	1.26-1.35	um
Trise / Tfall (20%-80%)	30	30	30	ps
RMS Spectral Width (max)	0.30	0.30	0.30	nm
Avg Launch Power (max)	0.0	0.0	0.0	dBm
Avg Launch Power (min)	-6	-6	-6	dBm
Avg Launch Power of OFF Transmitter (max)	-30	-30	-30	dB
Extinction Ratio (min)	6	6	6	dB
RIN (max)	-130	-130	-130	dB/Hz

Receive Characteristics (64B/66B)

Description				Units
Signal Speed	10.312	10.312	10.312	Gbd
Wavelength Range	1.26-1.35	1.26-1.35	1.26-1.35	nm
Avg Receive Power (max)	0.0	0.0	0.0	dBm
Receive Sensitivity	-17.0	-17.0	-17.0	dBm
Return Loss (min)	12.00	12.00	12.00	dBm
Stressed Rx Sensitivity	-14.12	-9.96	-9.23	dBm
Vertical Eye Closure Penalty	TBD	TBD	TBD	dB
Receive electrical 3dB Uper Cutoff Frequency (max)	15	15	15	GHz

Link Power Budget and Penalties (64B/66B)

Description				Units
Operating Distance	10	2	0.6	km
Zero Dispersion Wavelength	**1324**	**1324**	**1324**	MHz km
Wavelength Range	1.26-1.35	1.26-1.35	1.26-1.35	um
Link Power Budget	11	11	11	dB
Channel Insertion Loss	7.19	3.04	2.31	dB
Link Power Penalties	2.72	1.62	1.58	dB
Unallocated Margin	1.09	6.34	7.11	dB
Pisi	1.66	0.62	0.59	dB

Significant Changes from Proposed Link Parameters for 10km and 2kmLinks Indicated in RED

Receive Sensitivity Scaled to Picolight's ShortWave Recommended Spec

1300nm VCSEL SMF Link Conclusions

- 1300nm VCSEL solution offers:
  - DFB-like emission
  - lower cost than FP's or DFB's
  - lower power consumption
  - simplified thermal management
  - lower EMI
  - unified solution to 2km and 10km spec's
- 3.2Gb/s eye transmitted over 10km SMF at 1170nm
- 2km Spec should trade off λ vs $\Delta\lambda$ (enable wider-λ operation)
- Picolight time frame for commercialization of spec-compliant 1300nm VCSELs: late 2000

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