

# *Finisar*<sup>®</sup>

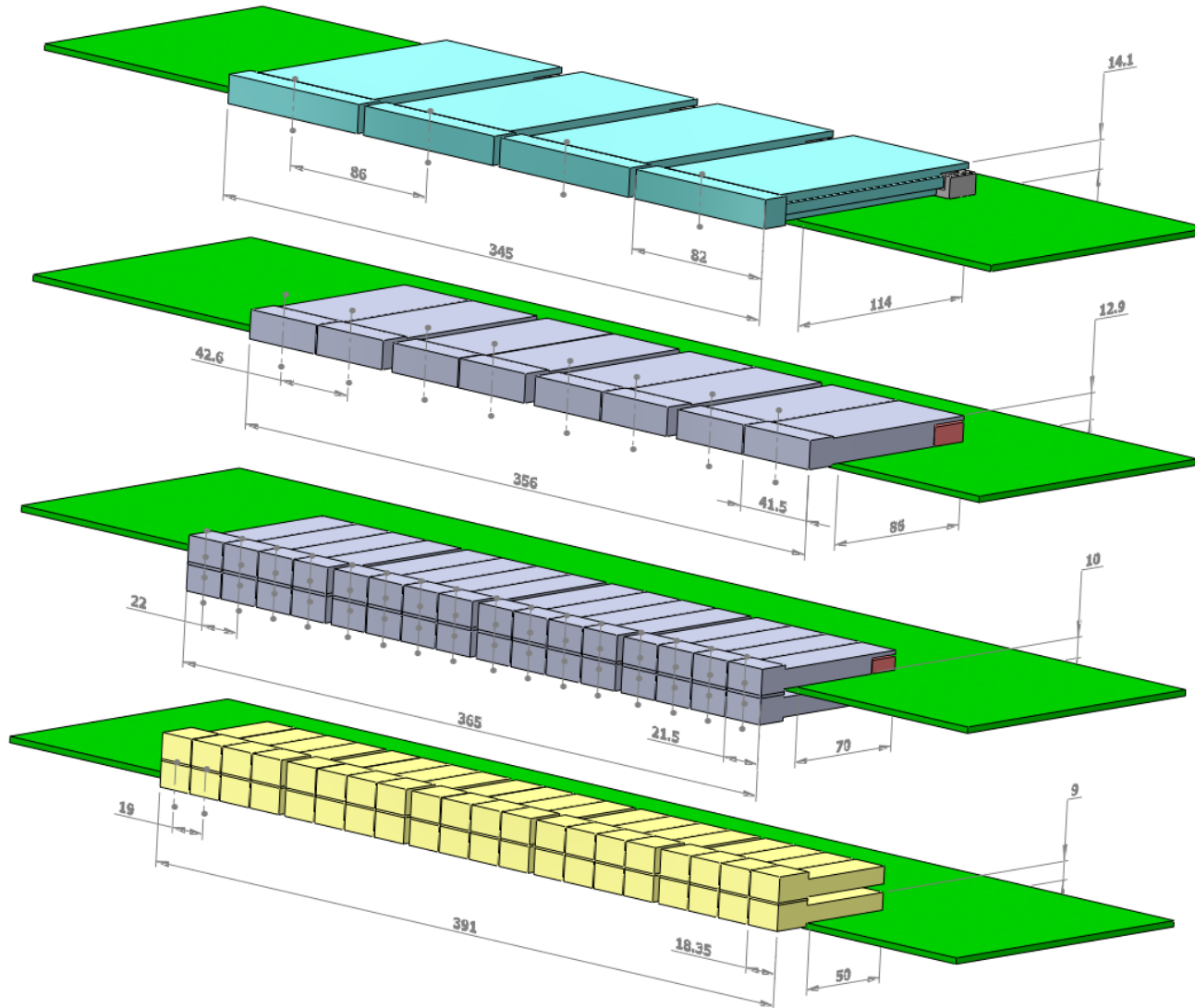
*Fiber Optic Solutions  
for High-Speed Networks*

## **What's Next for 100G and 400G Client Optics?** OFC 2014: Market Watch Panel 4



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# 100G Client Module Landscape



## 4x CFP

24W/16W

400 Gb/s per blade

## 8-10x CFP2

8W

800 Gb/s - 1 Tb/s per blade

## 16/32x CFP4

4.5W

1.6 – 3.2 Tb/s per blade

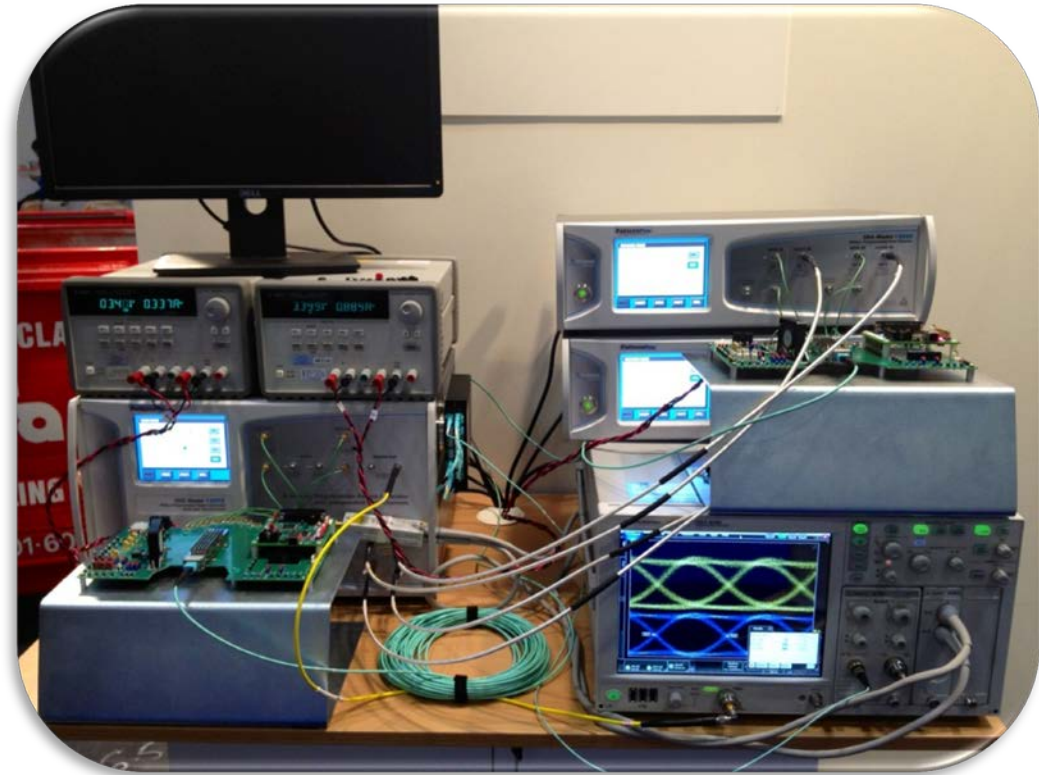
## 20/40\*x QSFP

3.5W

2-4 Tb/s per blade

\*if can cool stacked

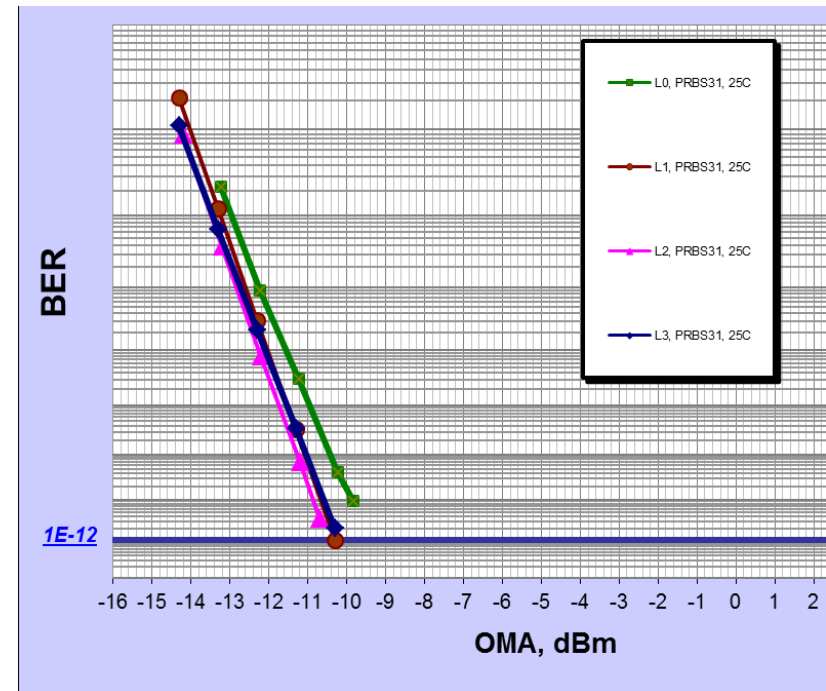
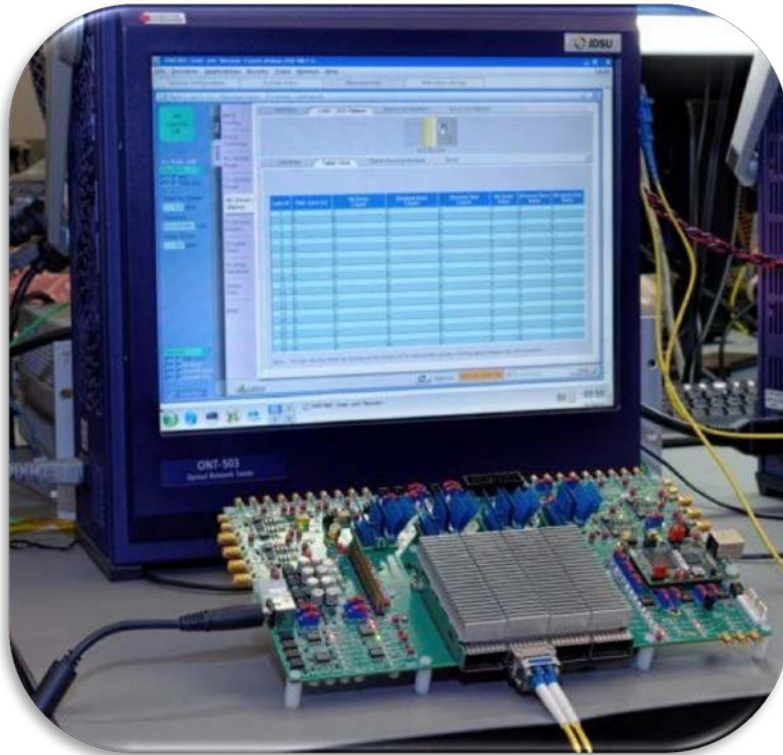
# CFP4 SR4 Demo – ECOC 2013



- ◆ 4x 25G VCSEL, 4x 25G PIN Rx
- ◆ 8x 25G CDRs
- ◆ 3.5 W



# 100G CFP4 LR4 (10 km) Demo – OFC 2014



- ◆ 4x 25G DFB TOSA, 4x 25G PIN ROSA, 8x 25G CDR
- ◆ 4W typical, 4.5W max
- ◆ CFP4 LR4 being shown by multiple companies



## 100G Client: Where Do We Go From Here?

- ◆ Reduced power needed to achieve all reaches CFP4, QSFP28
  - New power-efficient lasers and ICs in development
  
- ◆ Increased Density: How do we get beyond 4 Tb/s per blade?
  - Smaller form factor than QSFP28?
  - More channels in the existing form factors?
  
- ◆ Decreased Cost
  - 10G, lowest cost, highest volume device (SFP+) is single channel at line rate of electrical I/O, with no retiming
  - May need to change PMD's, i.e. migrate away from 4x25G

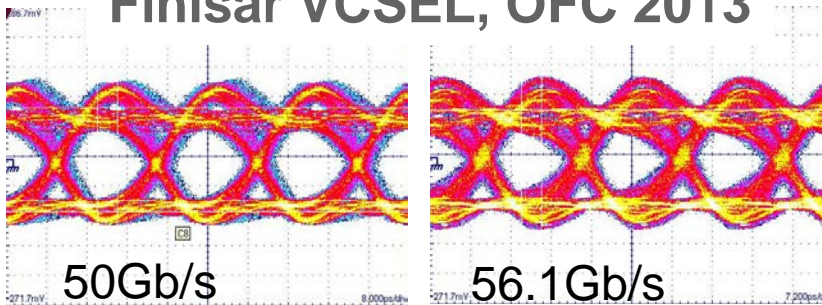
# 100GbE Roadmap

Technology Generation	CEI-28G	CEI-56G	CEI-112G
Electrical I/O	4x25G	2x50G	1x100G

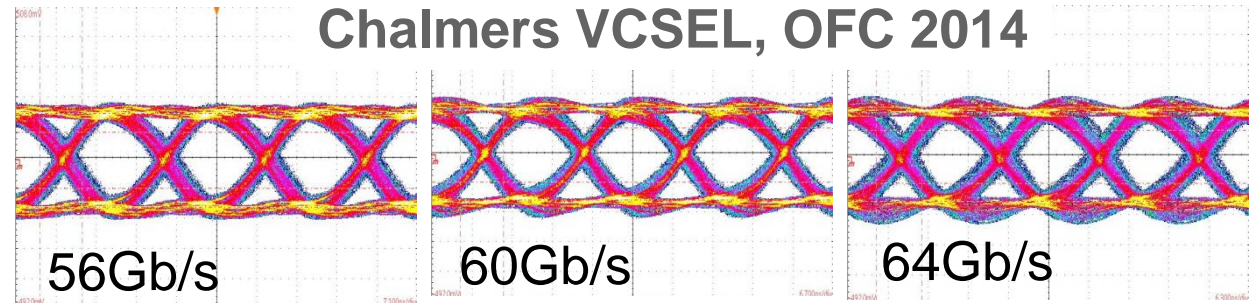
- ◆ Electrical interface is already defined to migrate from 4x25G to 2x50G to 1x100G (OIF)
- ◆ Should optics stay at 4x25G or migrate to match electrical rate?
- ◆ If migrate, next step will be 50G
  - Can achieve 50G with NRZ or with Higher Order Modulation (HOM)

# Directly Modulated VCSELs at >50 Gb/s

## Finisar VCSEL, OFC 2013



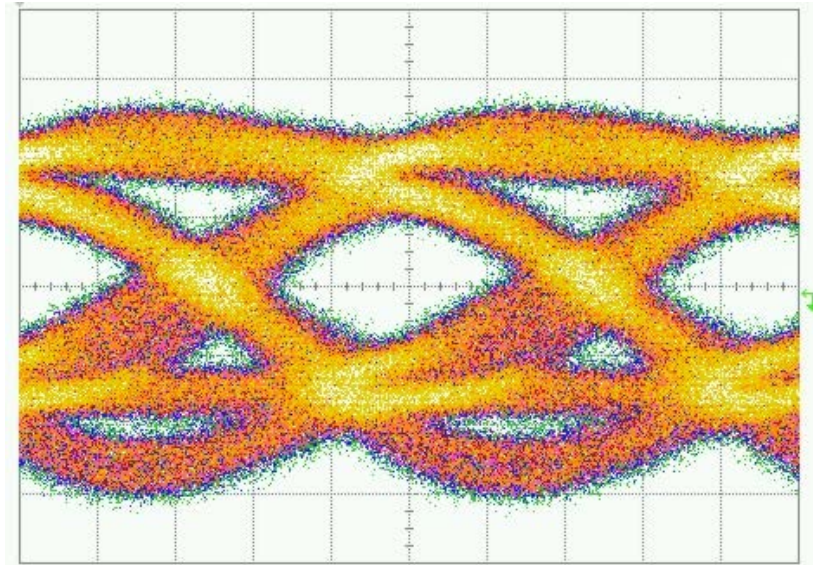
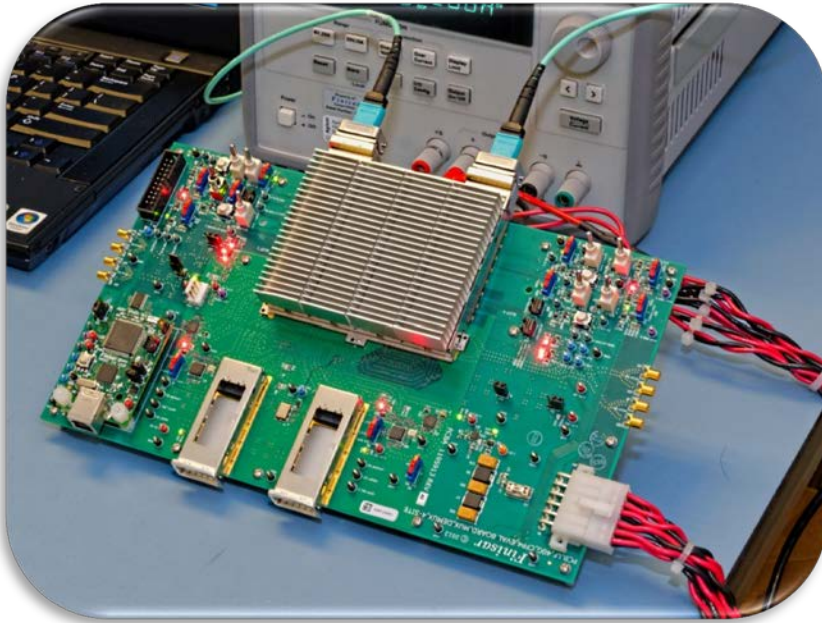
## Chalmers VCSEL, OFC 2014



- ◆ >50 Gb/s has been demonstrated with Directly-Modulated VCSELs (IBM/Finisar and IBM/Chalmers)
- ◆ 257m at 40G, 107m at 56G, and 57m at 64G have been demonstrated
- ◆ See D. Kuchta et al, paper Th3C.2 (OFC2014) for details



# 40G Serial VCSEL Technology Demo - OFC 2014



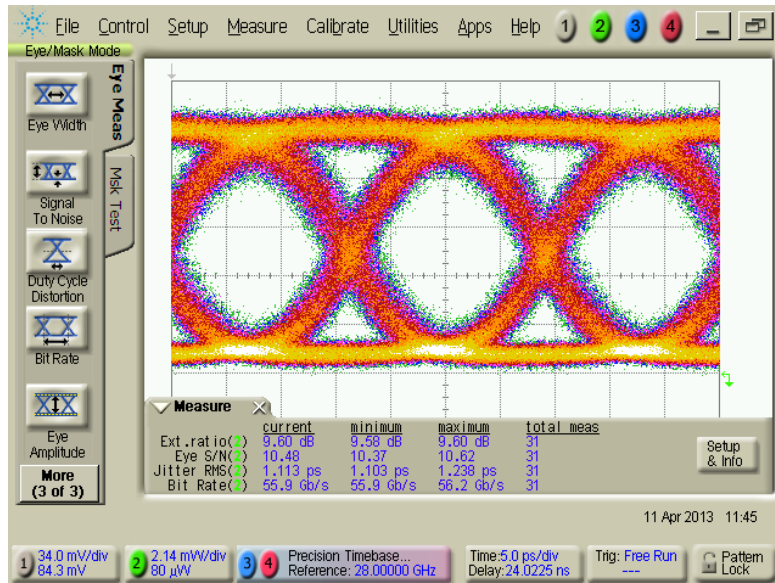
**Tx eye after 100m, OM4 fiber**

- ◆ 40G VCSEL Tx and PIN Rx, 2x 40G CDR
- ◆ Error-free operation at 40G over 100m over OM4 duplex fiber with IEEE standard FEC



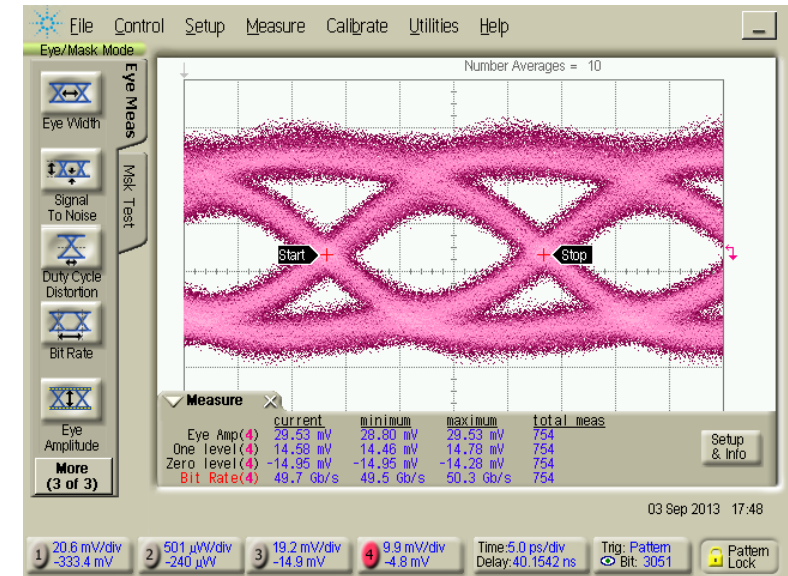
# 50G Client: 1.3 um Modulators (InP or Si)

## 56G eye, InP Modulator



Source: HHI

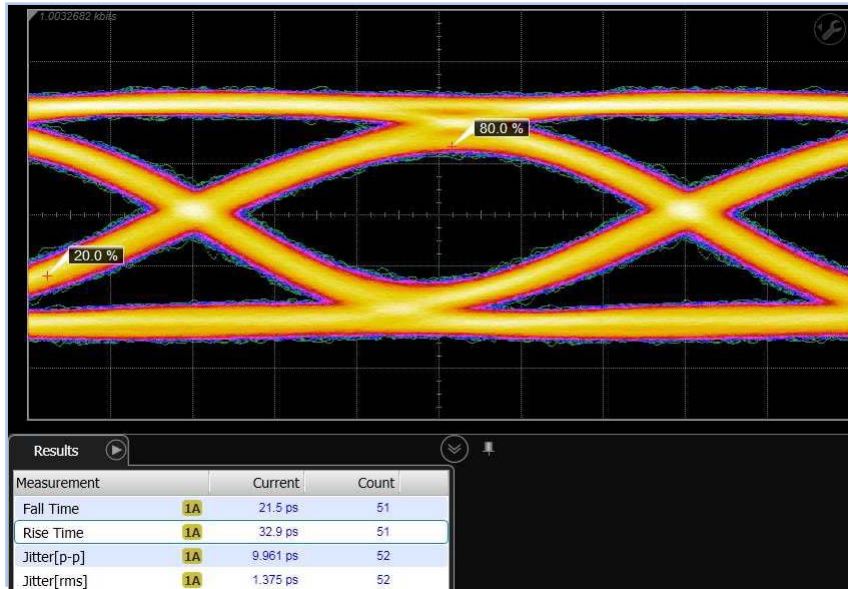
## 50G eye, Silicon Modulator



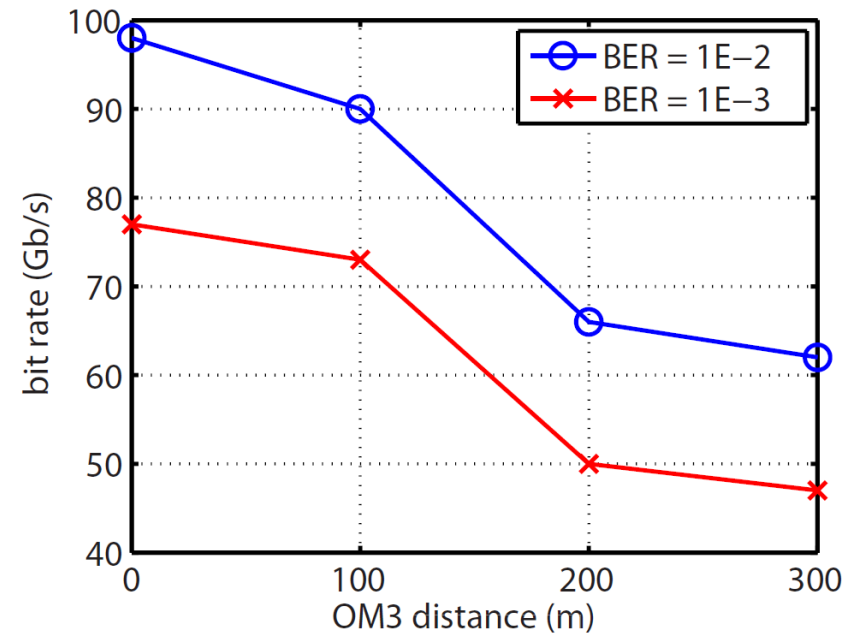
Source: SLS/OpSIS/Finisar

**1.3 um, 50G Modulators have been demonstrated in InP and Silicon**

# 50 Gb/s Using 25 Gb/s VCSELs and Higher

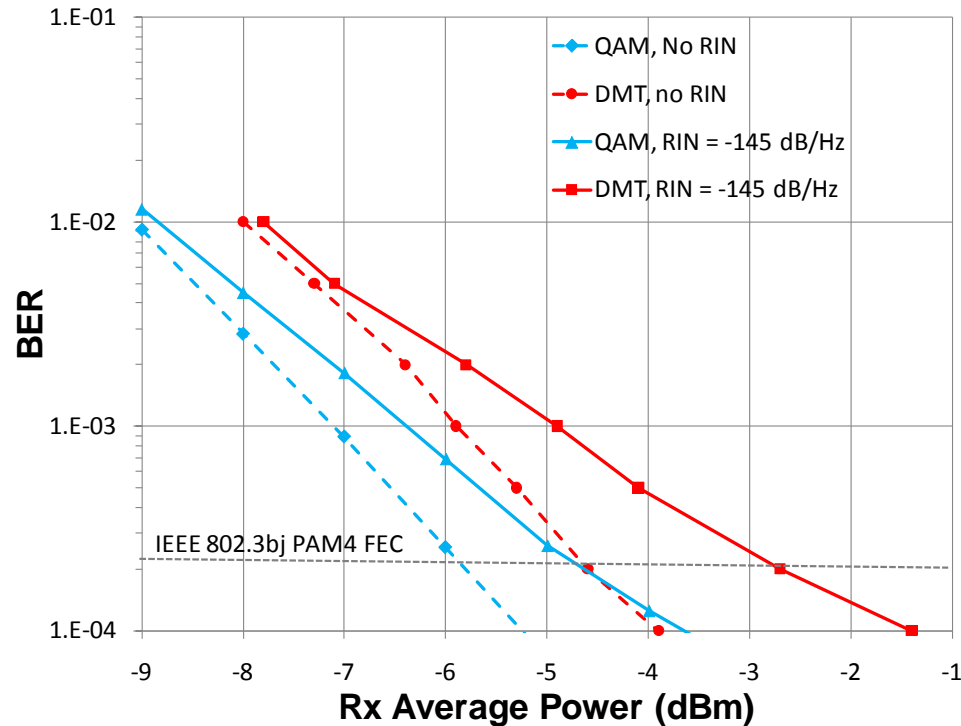


Back to Back NRZ eye for 25Gb/s VCSEL



- ◆ Experimental demonstration of 50 Gb/s through 300m OM3 using production-grade Finisar 25G VCSEL
- ◆ Achieved using discrete multitone (DMT) modulation and a 20% FEC overhead

# >100Gb/s Demonstrated with One 25G DFB and Higher Order Modulation

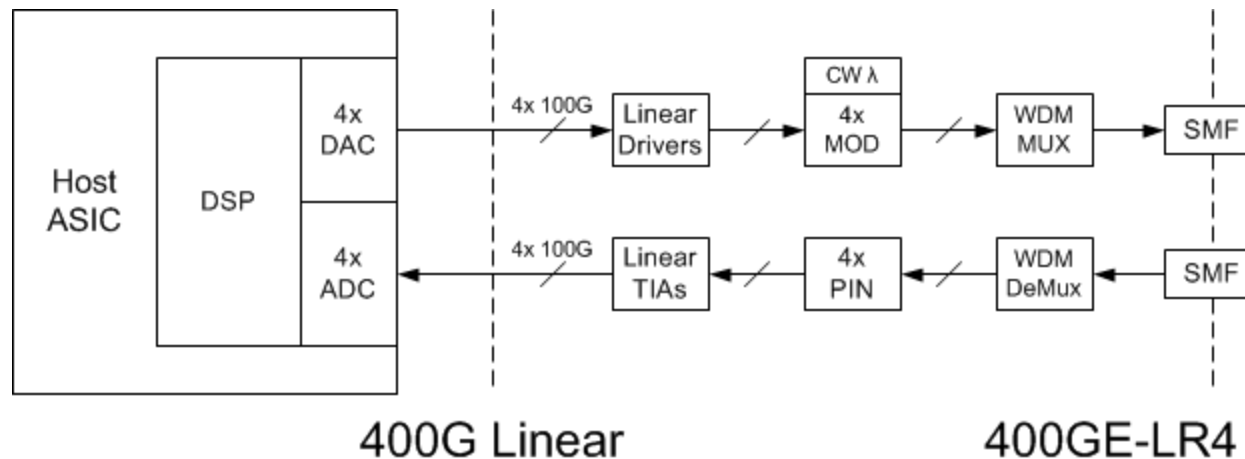


- ◆ 100G per channel with one 25G DFB demonstrated using both QAM and DMT
- ◆ Choice of modulation format depends on tradeoffs of performance vs. power consumption
- ◆ See Lyubomirsky and Ling, W1F.4



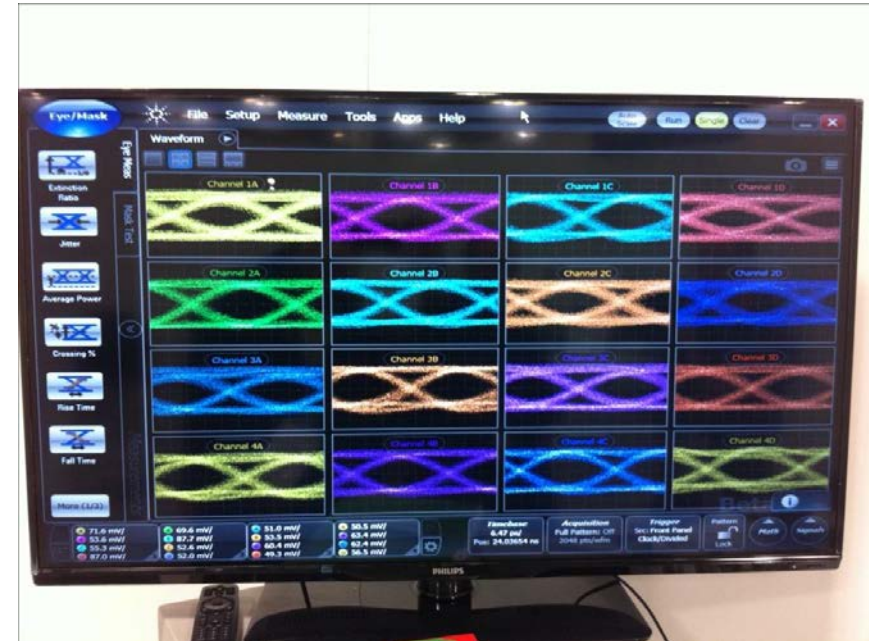
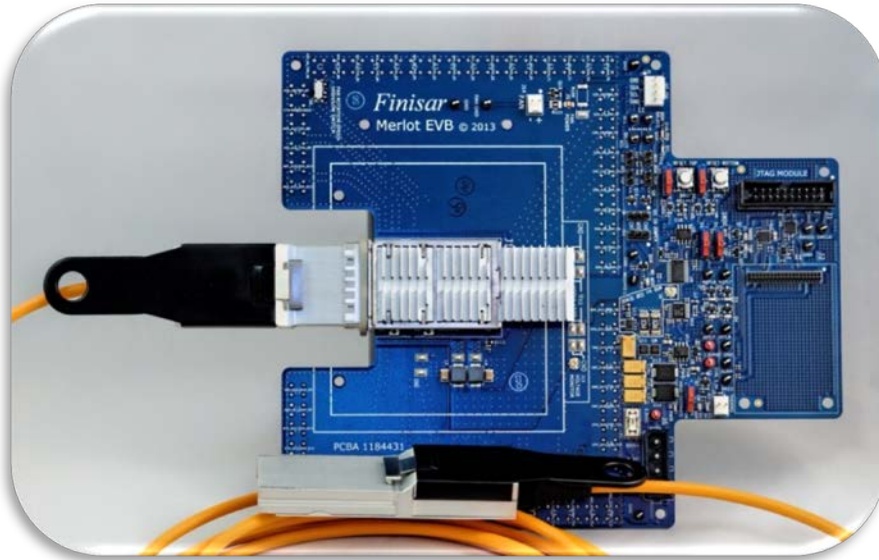
# 400G Standard Proposal

## 3<sup>rd</sup> Gen standard proposal



- ◆ 1<sup>st</sup> Gen 400G will be 16x25G
- ◆ 2<sup>nd</sup> Gen Proposals for Higher Bandwidth Density
  - ◆ 8x 50Gb/s NRZ
  - ◆ 4x 50GBaud with PAM4 or other higher order modulation
- ◆ 3<sup>rd</sup> Gen: 4x 100GBaud requires higher order modulation

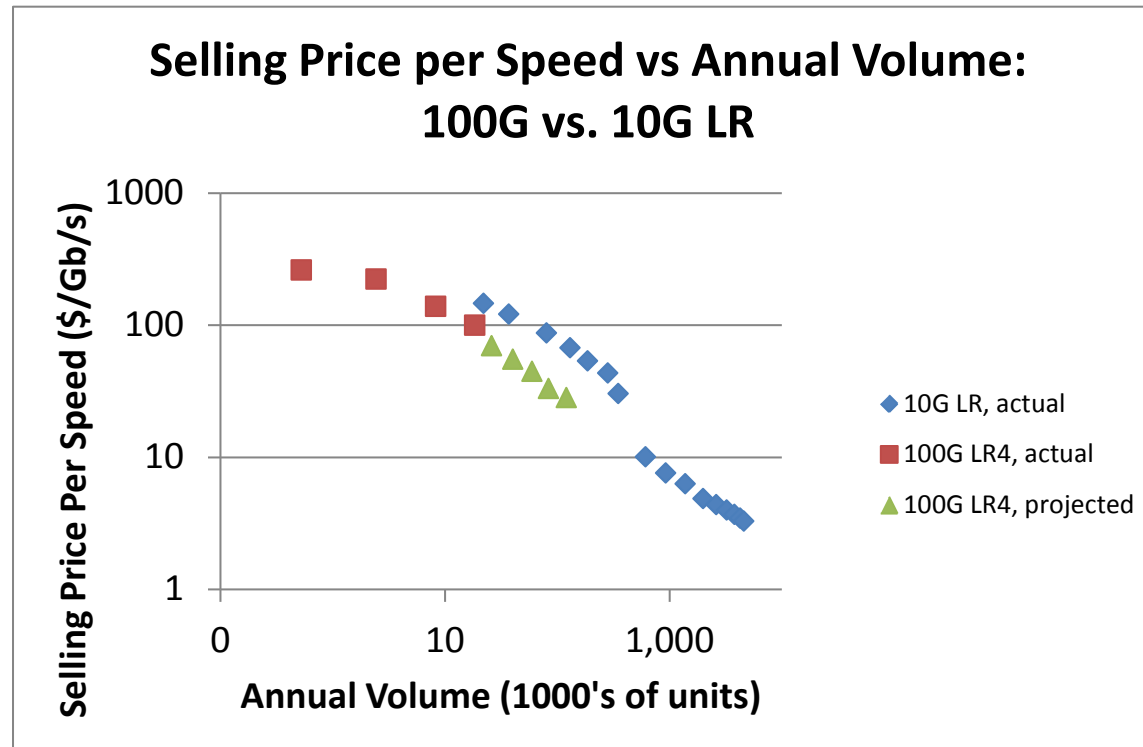
## 400G 16x25 VCSEL 100 m Demo: OFC2014



16x 25G Rx eyes

- ◆ 16x 25 G VCSEL transmitters, 16x 25 G receivers, 32x 25G CDRs in 1" x 3" pluggable form factor (cable)
- ◆ 100m with FEC

# Update: Price of 100G Relative to 10G (10 km)



*Data courtesy LightCounting*

- ◆ 100G pricing is below bit-parity with 10G at equivalent volumes
- ◆ 10G price discontinuity at 1M cumulative units
- ◆ Best way to reduce 100G pricing: Bring on the volume!



## Summary: 100G/400G Client Present and Future

- ◆ 100G form factors CFP4 and QSFP28 support up to 4 Tb/s per line card
- ◆ 400G first implementation likely 16 x 25G
- ◆ Future 100G/400G potential needs:
  - Power efficient laser and IC development
  - 50G NRZ VCSELs, modulators
  - 50G, 100G higher order modulation with VCSEL, DML, modulators
- ◆ No consensus on NRZ vs. HOM for 50G
  - No consensus on modulation format of HOM for 50G or 100G
  - Unlike 100G roadmap 7 years ago, the future is uncertain
- ◆ 100G power, size decreased ~2X faster than 10G. 100G prices below bit parity with 10G at equivalent volumes – Bring on the volume!