Radiation-Hard/High-Speed Parallel Optical Links

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July 6, 2012

Outline

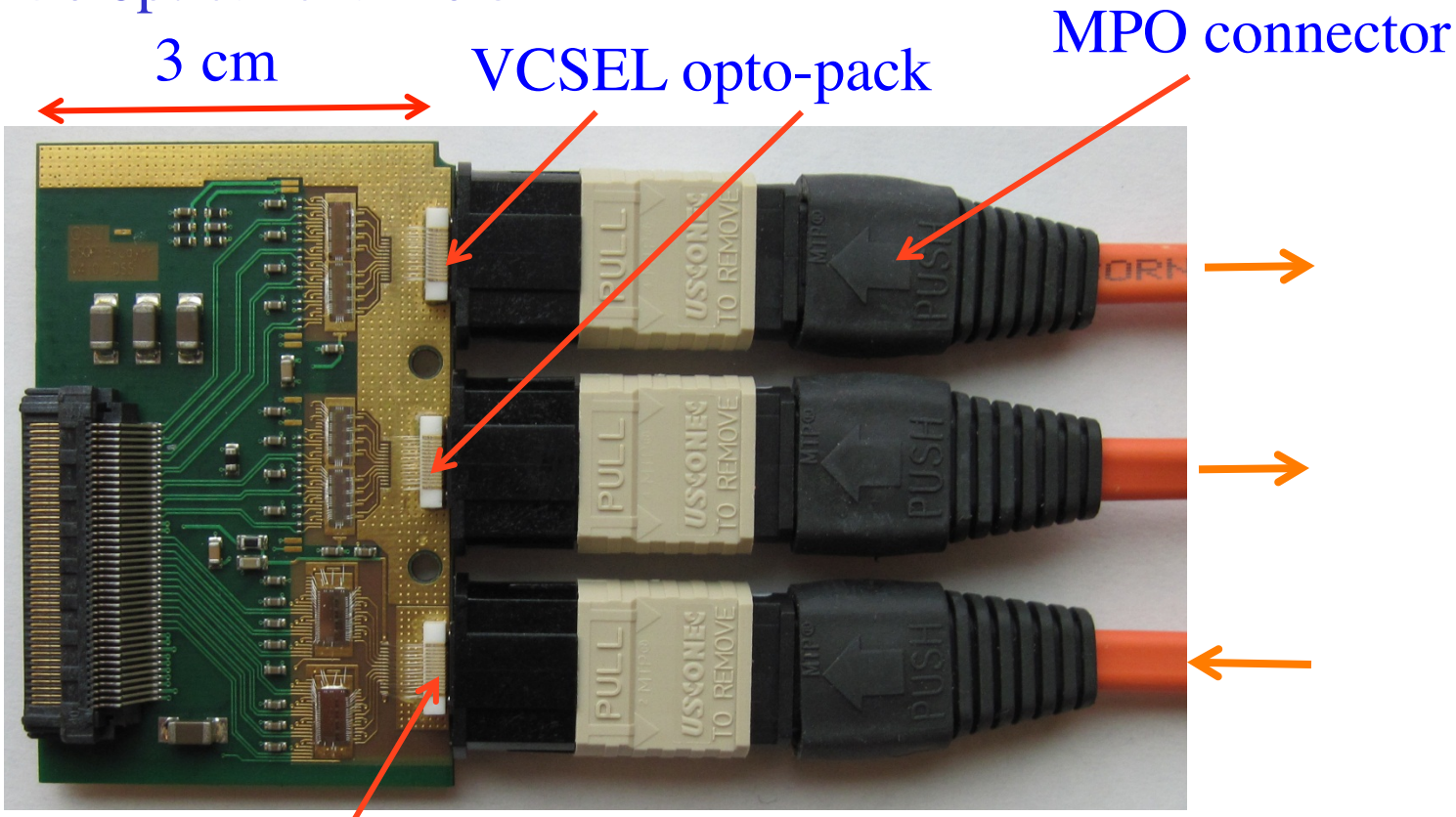
- Introduction to a compact solution
- Results with 5 Gb/s VCSEL array driver
- Summary

Use of VCSEL Arrays in ATLAS

- Widely used in off-detector data transmission
- First on-detector implementation in pixel detector
  - experience has been positive
    - VCSELs used are humidity sensitive but they are installed in very low humidity location
    - modern VCSELs are humidity tolerant
    - ⇨ will use arrays for next pixel detector upgrade (IBL)

New Parallel Optical Engine

- Improved design for new pixel layer of ATLAS
  - use 12-channel VCSEL and PIN arrays
  - ⇨ 36 optical channels

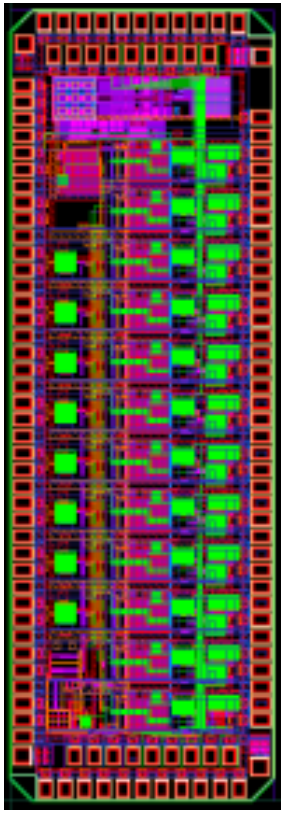


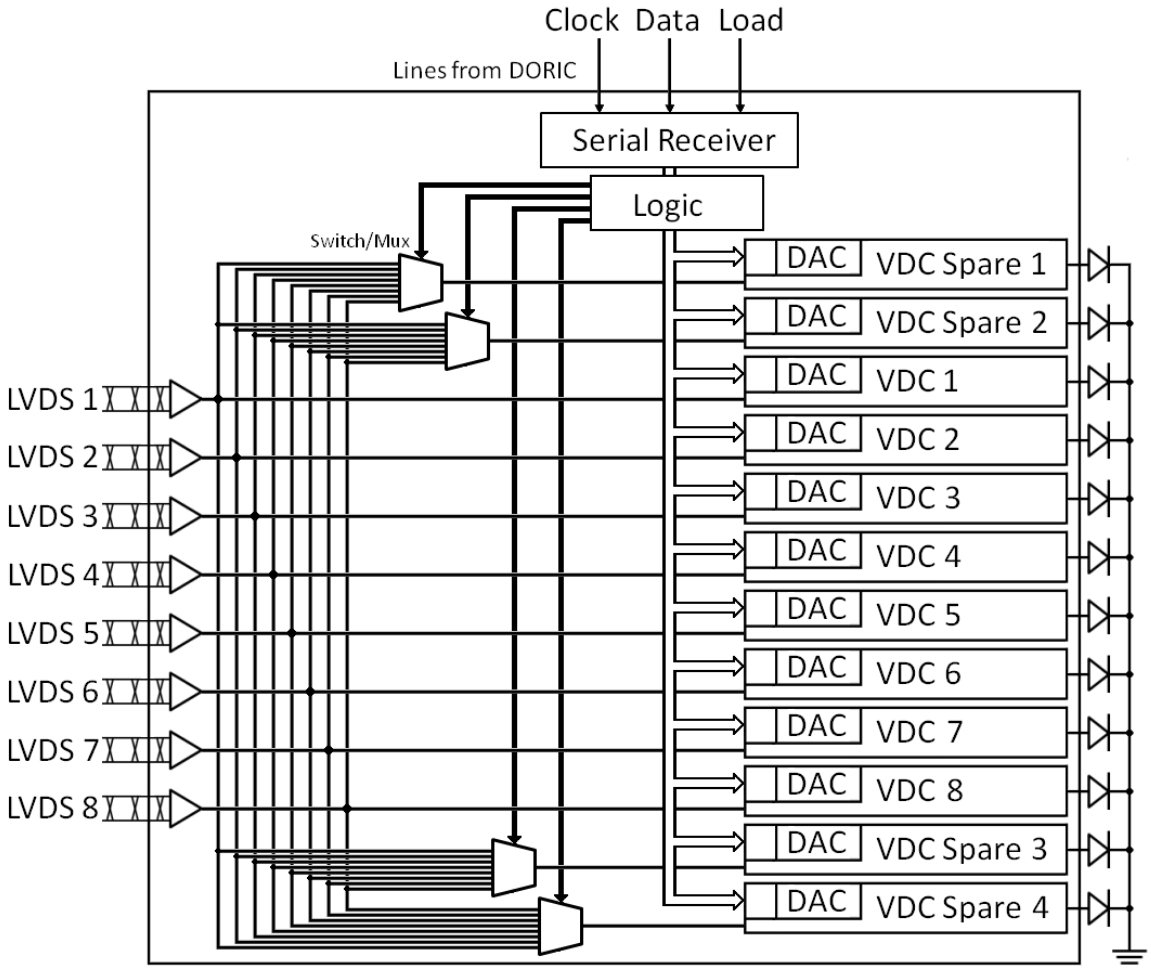
New 12-Channel VCSEL Driver

- New ASIC designed using 130 nm CMOS
- Incorporate improvements taking advantage of experience from 1st generation parallel optical engine:
  - redundancy to bypass a broken VCSEL
    - special thanks to FE-I4 group (Roberto Beccherle et al.) for command decoder circuit
  - power-on reset in case of communication failure:
    - no signal steering
    - 10 mA modulation current (on current)
    - 1 mA bias current (off current)
- Will only operate at 160 Mb/s for new pixel layer but designed ASIC to operate at much higher speed (5 Gb/s) to gain experience in designing high-speed parallel driver

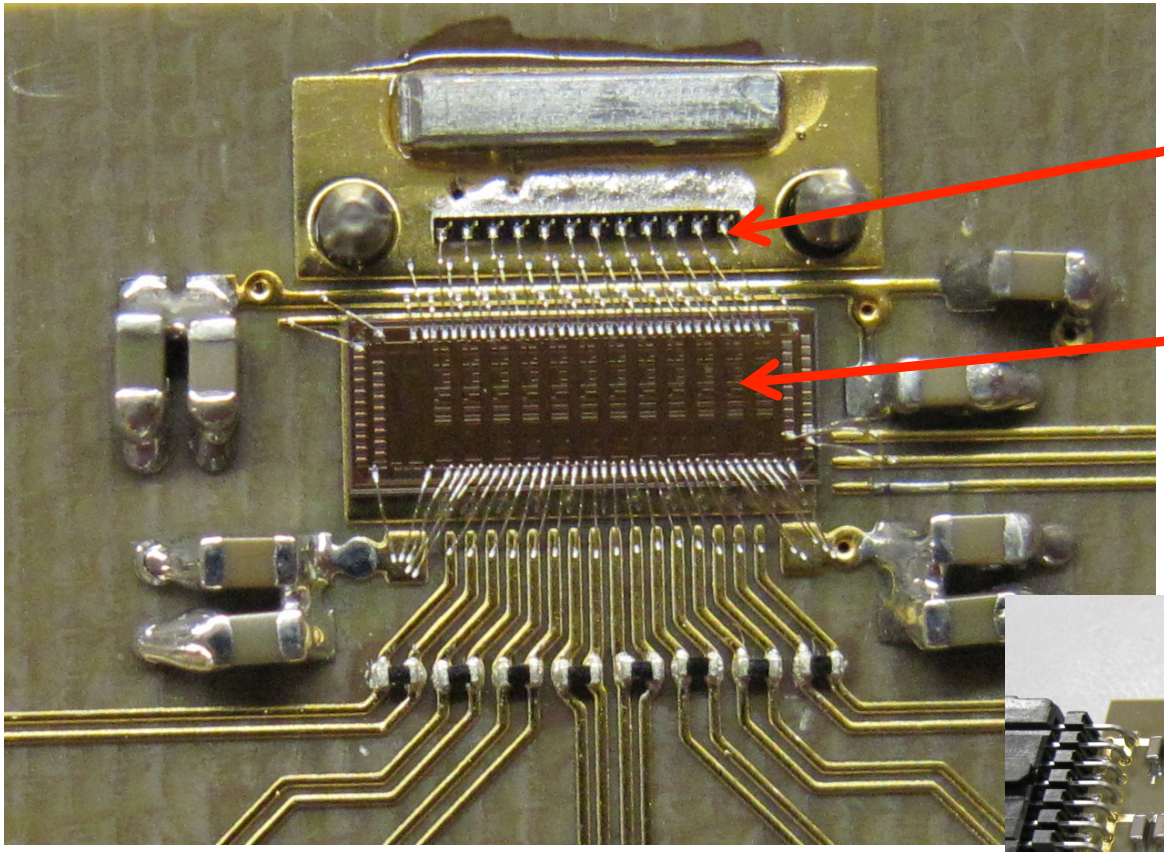
New VCSEL Array Driver

- Only inner 8 channels connected to new pixel modules
  - future driver should reserve only one channel for redundancy





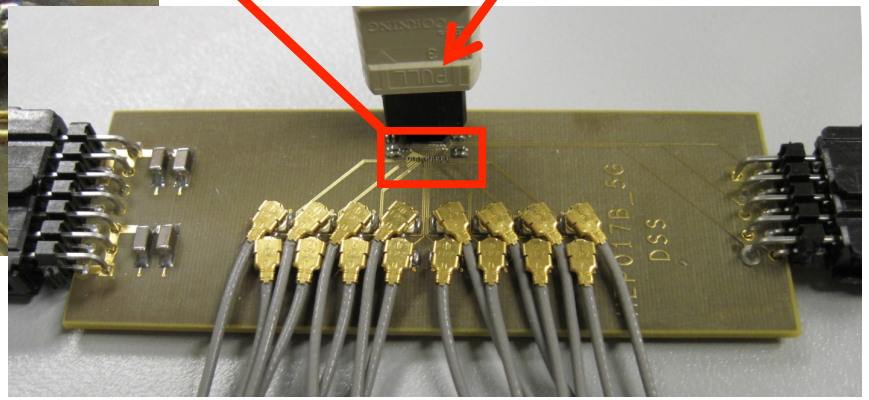
High-Speed Test Configuration



10 Gb/s ULM
VCSEL array

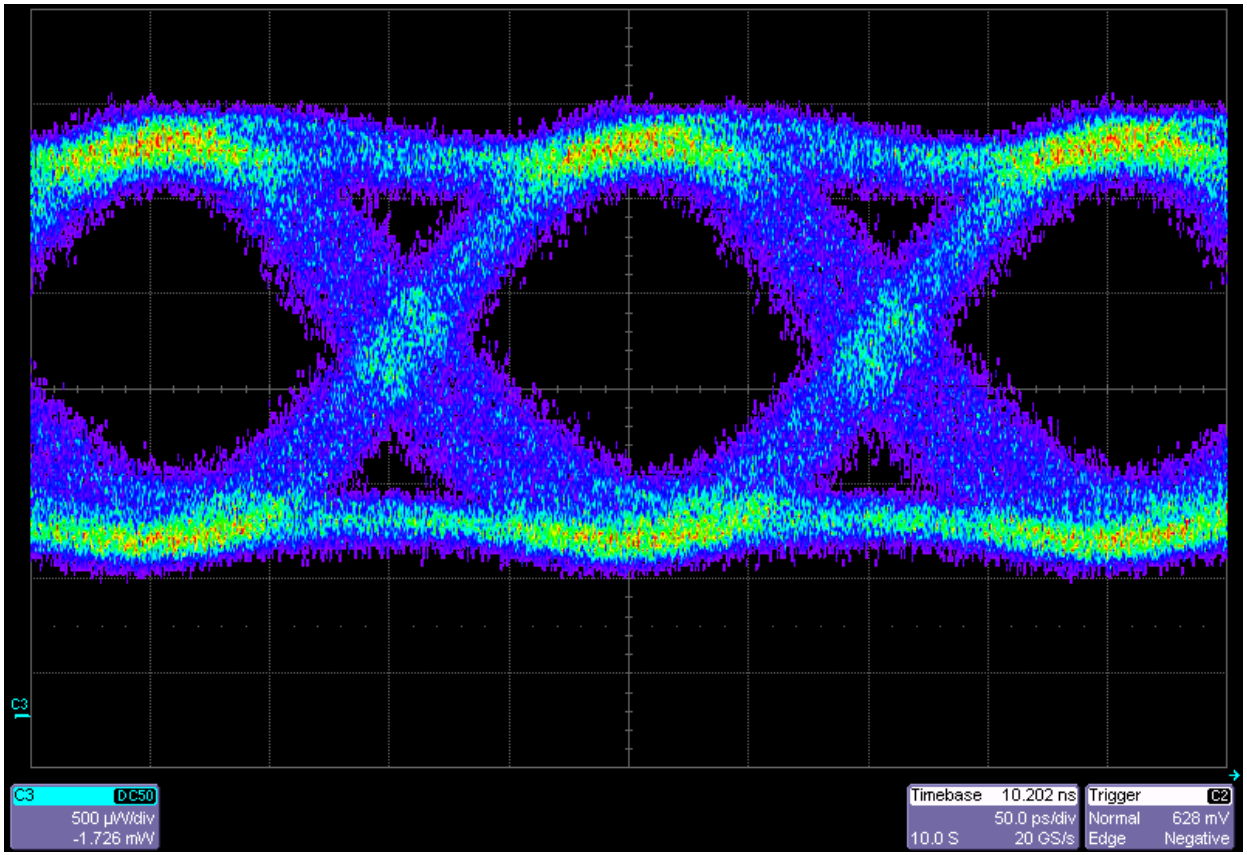
VCSEL
array driver

MPO connector

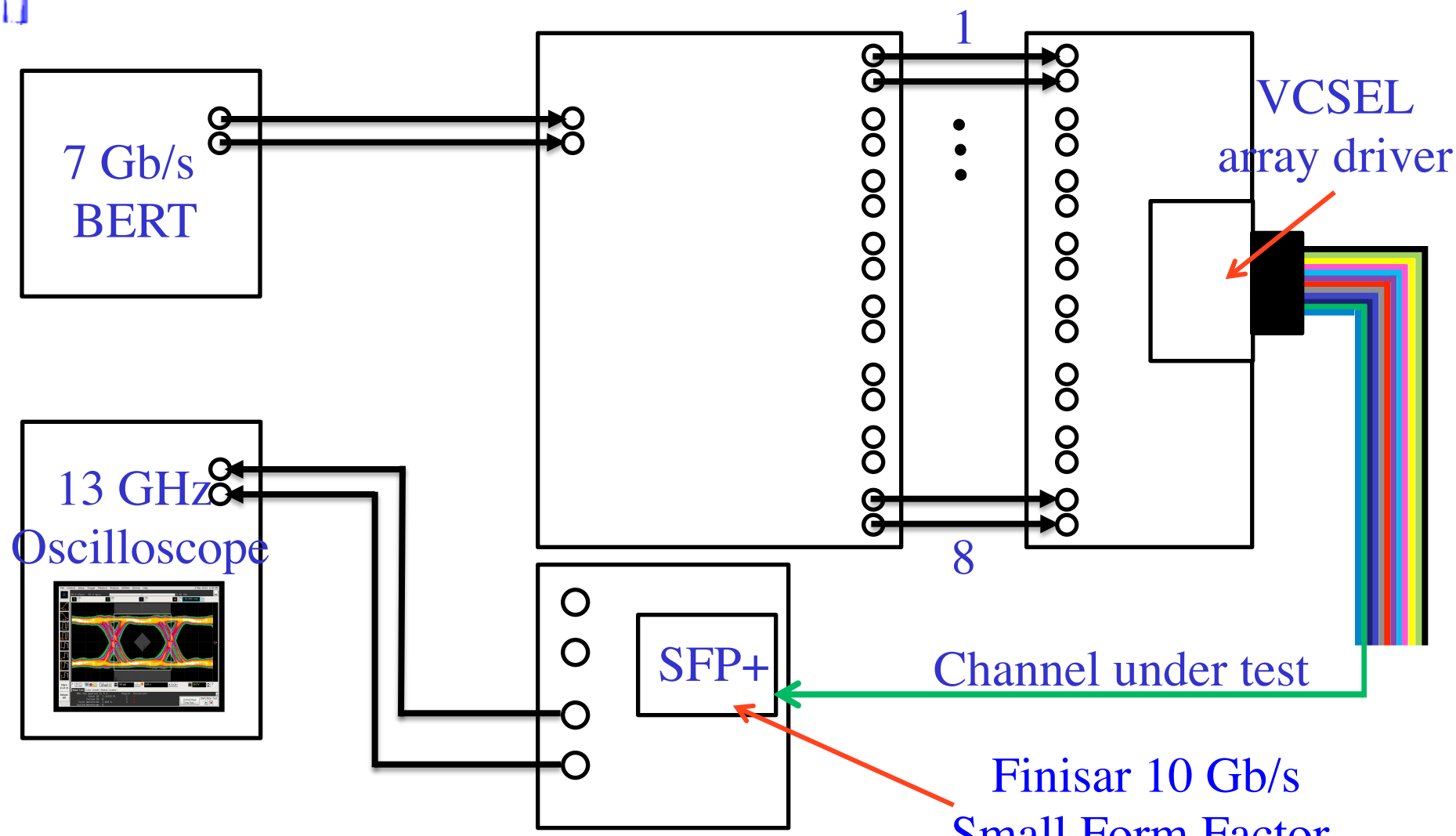


Optical Eye Diagram

- Difficult to judge eye diagram with 4.5 GHz optical probe…

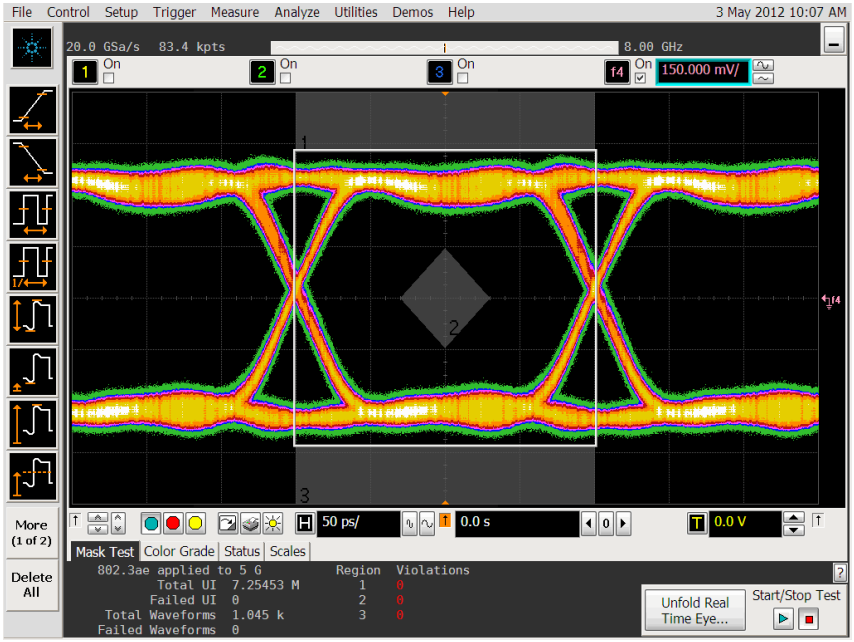


SFP+ as Optical Probe

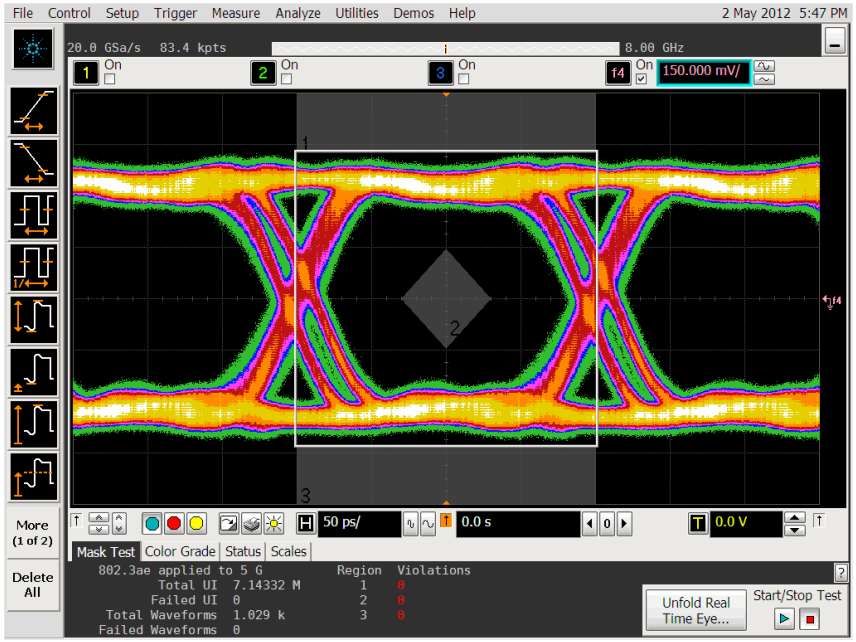


SFP+ Loopback vs VCSEL Driver

10 Gb/s SFP+ transceiver @ 5 Gb/s
with optical loopback

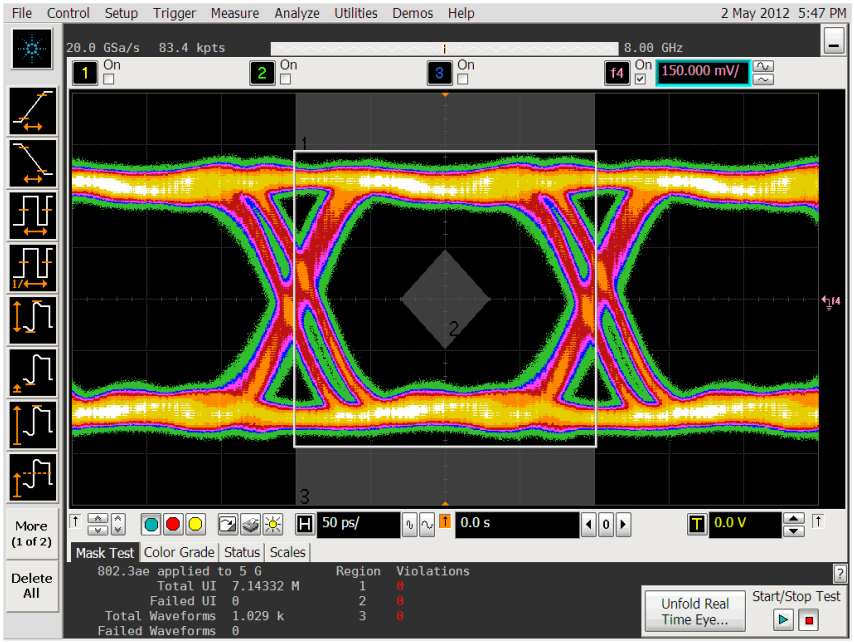


VCSEL driver @ 5 Gb/s
after 10 Gb/s SFP+ receiver

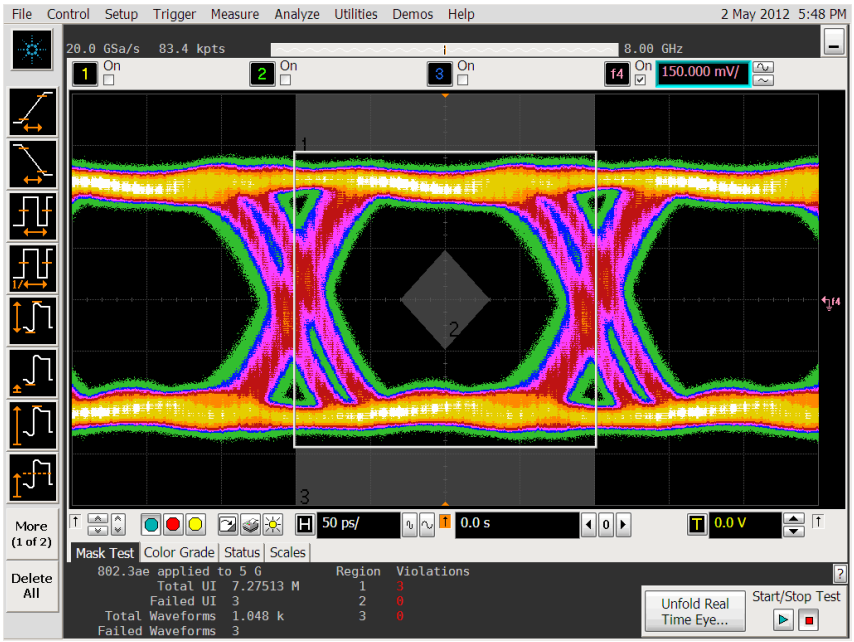


Eye with One/All Channels Active

One channel active



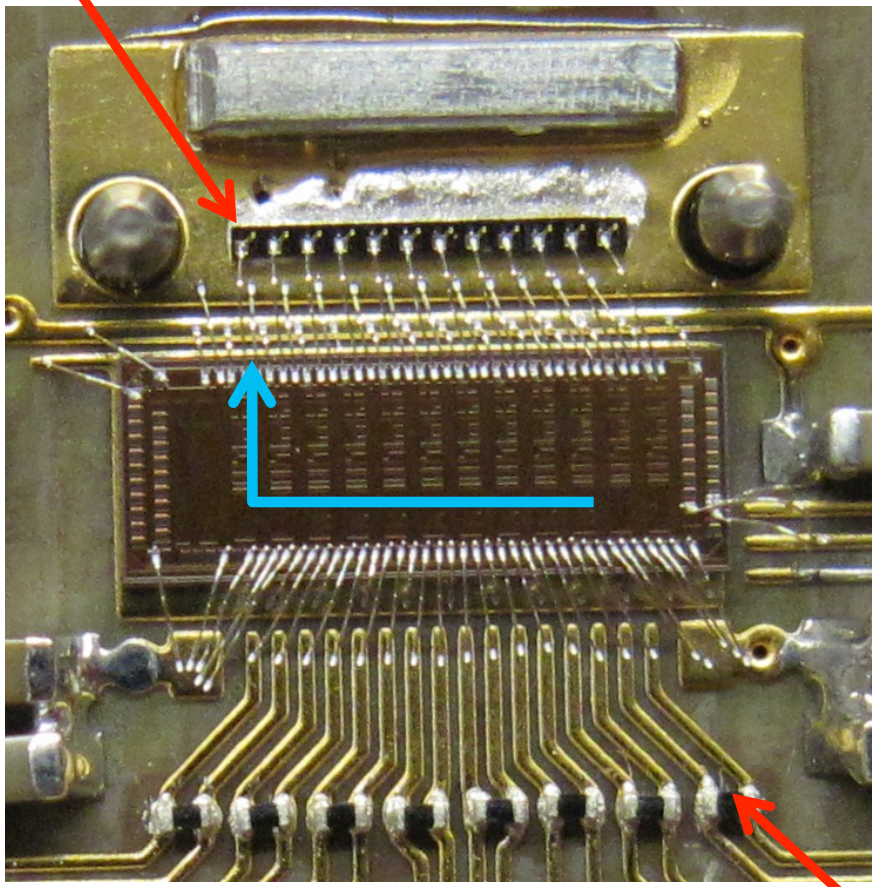
All channels active



- all channels work @ 5 Gb/s with bit error rate < 5×10^{-13} for all channels active
- jitter increases with all channels active but still passes the mask test

Effect of Steering on Eye

VCSEL spare 1

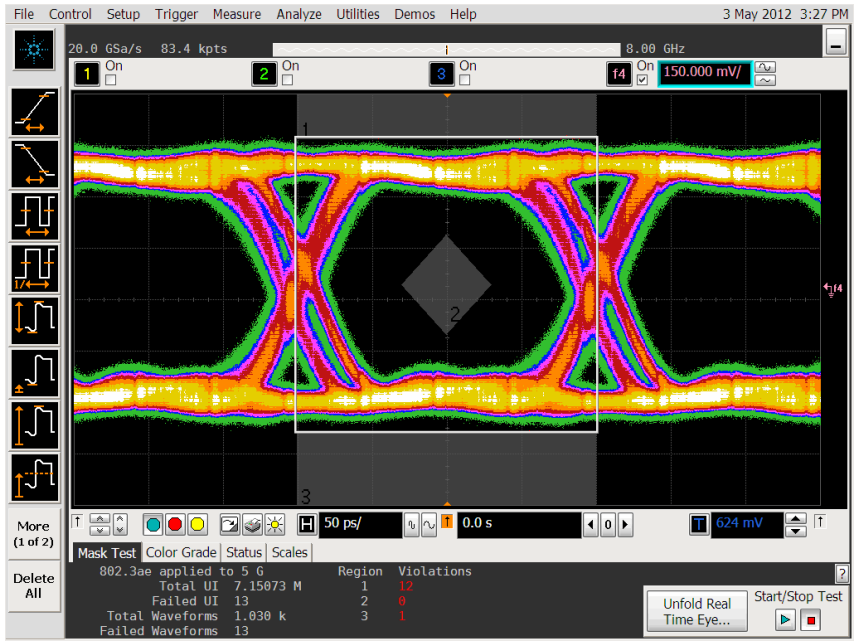


Receiving LVDS signal from channel 8, steering to VCSEL spare 1

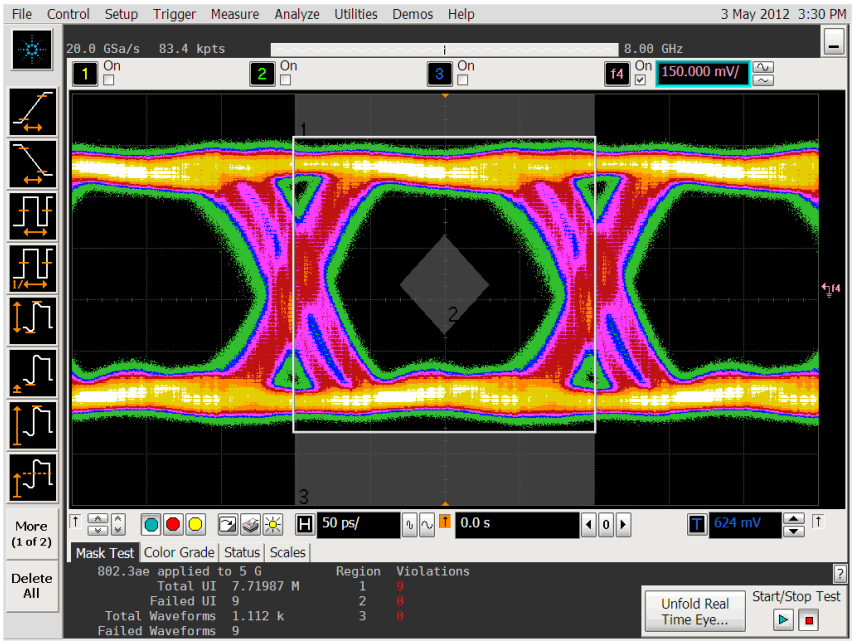
LVDS in channel 8

Effect of Steering on Eye

Spare 1 output with other channels off



Spare 1 output with all channels active

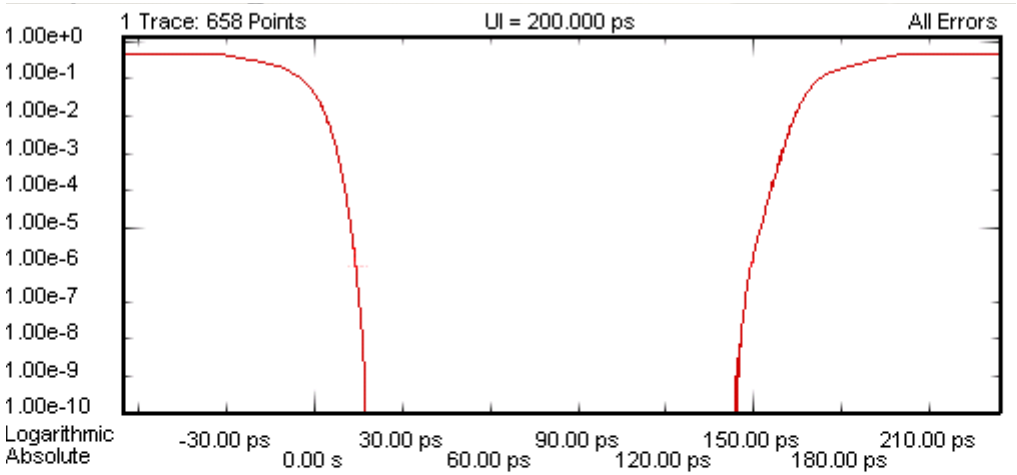


- steered channel still passes the mask test
  - jitter increases with all channels active

Jitter Measurement

- measured on the spare channel with signal rerouted across die
  - should be the worse case scenario
- all other channels active

Total Jitter @ BER 10^{-12}	65 ps
Random Jitter	3.1 ps
Total DJ	36.8 ps



Radiation Hardness

- 10 Gb/s VCSEL arrays have been proven to be radiation hard to tens of Mrad
  - send signal on ~1 m micro co-ax cables to less radiation and more serviceable location
- Radiation hardness of VCSEL array driver will be verified in the summer

Future Plan

- 10 Gb/s transmission needed
  for ATLAS inner pixel layer and LAr readout upgrades
  - joint ATLAS/CMS proposal funded
    via US DOE generic R&D program
- Layout array VCSEL driver/PIN receiver using
  GBLD and GBTIA with redundancy for possible pixel applications

Summary

- VCSEL array offers compact solution to data transmission
- 5 Gb/s VCSEL array driver successfully prototyped
- Currently designing 10 Gb/s VCSEL array driver