



# Results on Opto-Link R&D

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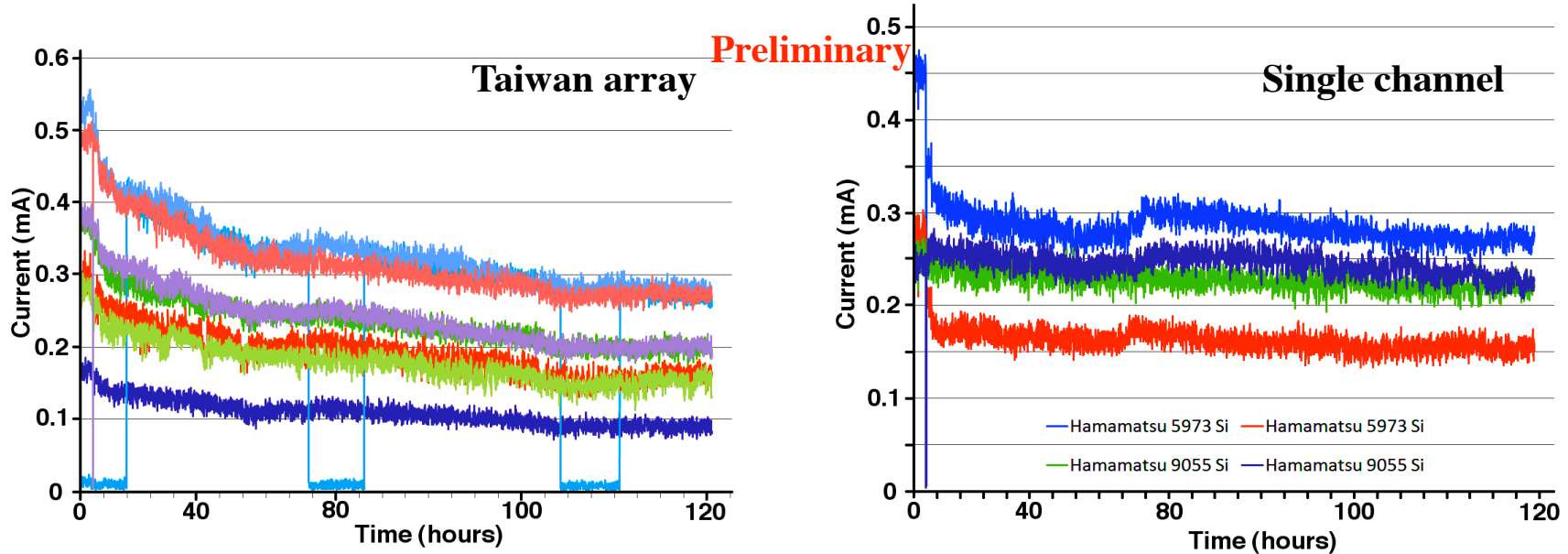
# Outline



- Radiation hardness of PIN arrays
- Radiation hardness of VCSEL arrays
- Study of opto-chips
- Summary



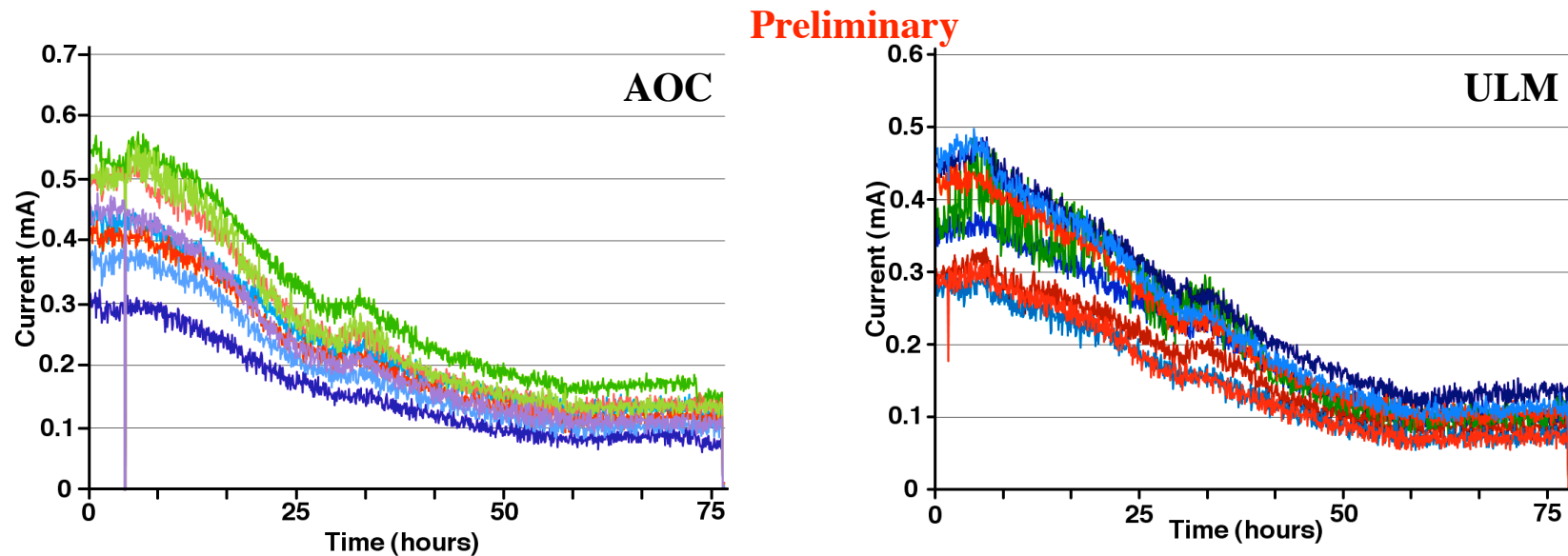
# Radiation-Hardness of Silicon PIN



- irradiate PIN with 24 GeV protons at CERN
  - ◆ SLHC dosage:  $2.6 \times 10^{15}$  p/cm<sup>2</sup> ( $1.5 \times 10^{15}$  1-MeV  $n_{eq}$ /cm<sup>2</sup>)
  - ◆ 2007 irradiation with 60% higher dosage:
    - Taiwan array responsivity (A/W): decrease by a factor of 3
  - ◆ 2008 irradiation with SLHC dosage:
    - Taiwan array responsivity: decrease by a factor of 2
    - Hamamatsu device responsivity: decrease somewhat less



# Radiation-Hardness of GaAs PIN



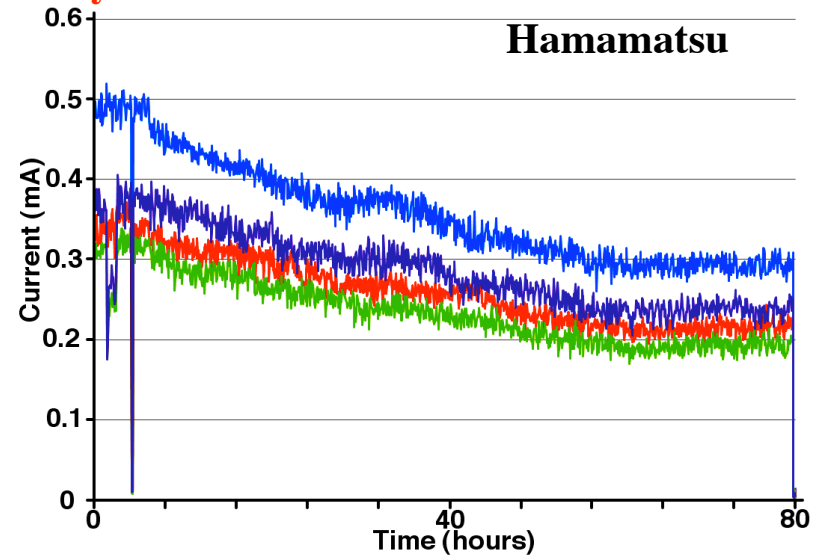
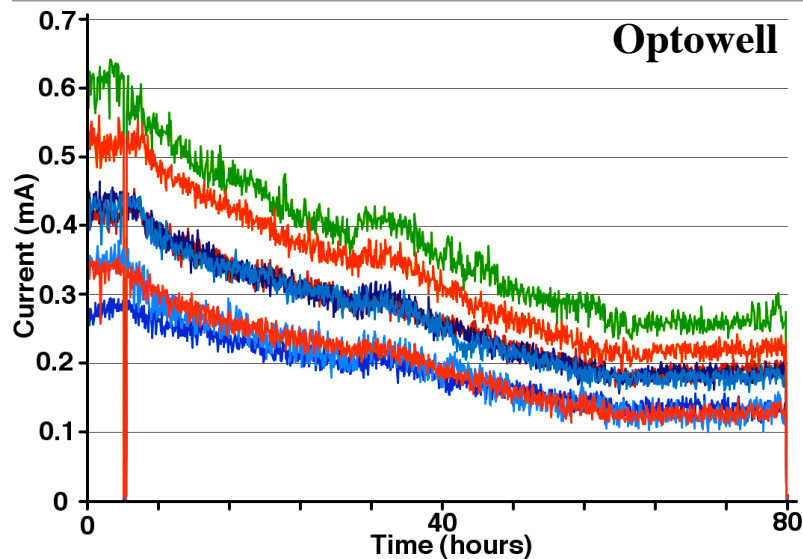
- irradiate PIN with 24 GeV protons at CERN
  - ◆ SLHC dosage:  $2.6 \times 10^{15}$  p/cm<sup>2</sup> ( $8.2 \times 10^{15}$  1-MeV  $n_{eq}$ /cm<sup>2</sup>)
  - ◆ 2007 irradiation with 60% higher dosage:
    - responsivity: decrease by a factor of 10
  - ◆ 2008 irradiation with SLHC dosage:
    - responsivity: decrease by a factor of 2-4



# Radiation-Hardness of GaAs PIN



Preliminary



- 2007 irradiation with 60% higher dosage:
  - ◆ Optowell responsivity: decrease by a factor of 10
- 2008 irradiation with SLHC dosage:
  - ◆ Optowell responsivity: decrease by a factor of  $\sim 2$
  - ◆ Hamamatsu responsivity: decrease by a factor of  $\sim 1.6$



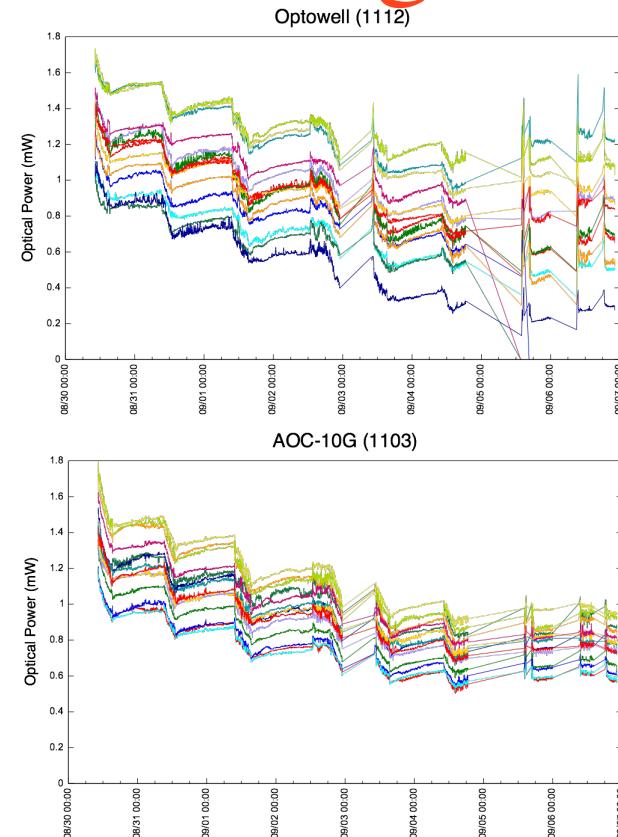
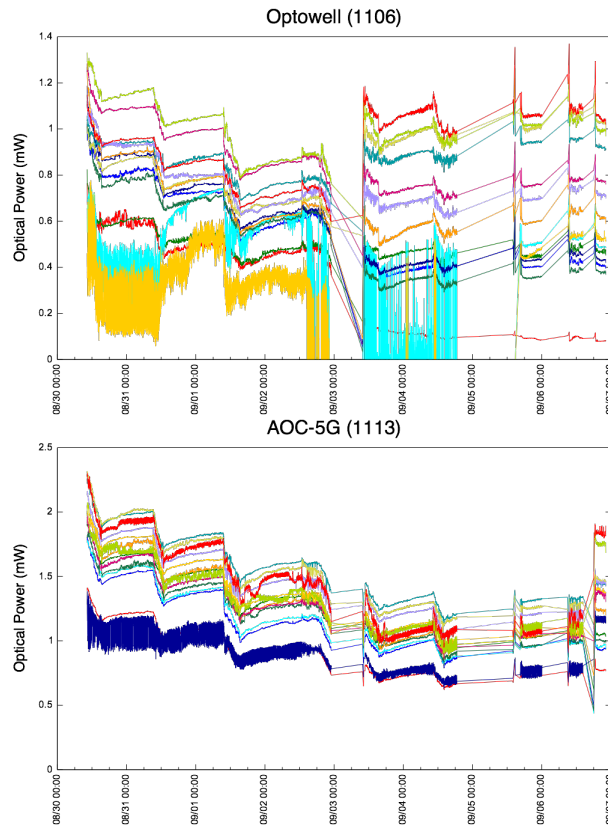
# Radiation-Hardness of PIN



|                 | Gb/s    | Responsivity (A/W) |      |
|-----------------|---------|--------------------|------|
|                 |         | Pre                | Post |
| GaAs            |         |                    |      |
| ULM             | 4.25    | 0.50               | 0.13 |
| AOC             | 2.5     | 0.60               | 0.19 |
| Optowell        | 3.125   | 0.60               | 0.25 |
| Hamamatsu G8921 | 2.5     | 0.50               | 0.32 |
| Si              |         |                    |      |
| Taiwan          | 1.0     | 0.55               | 0.33 |
| Hamamatsu S5973 | 1.0     | 0.47               | 0.37 |
| Hamamatsu S9055 | 1.5/2.0 | 0.25               | 0.21 |



# VCSEL Power vs Dosage



- 2007 irradiation with 60% higher dosage:
  - ◆ close to zero power on some channels
- 2008 irradiation with SLHC dosage:
  - ◆ AOC(5 & 10 G) have good power





# Opto-Chips

0.13  $\mu\text{m}$

640 Mb/s VCSEL Driver

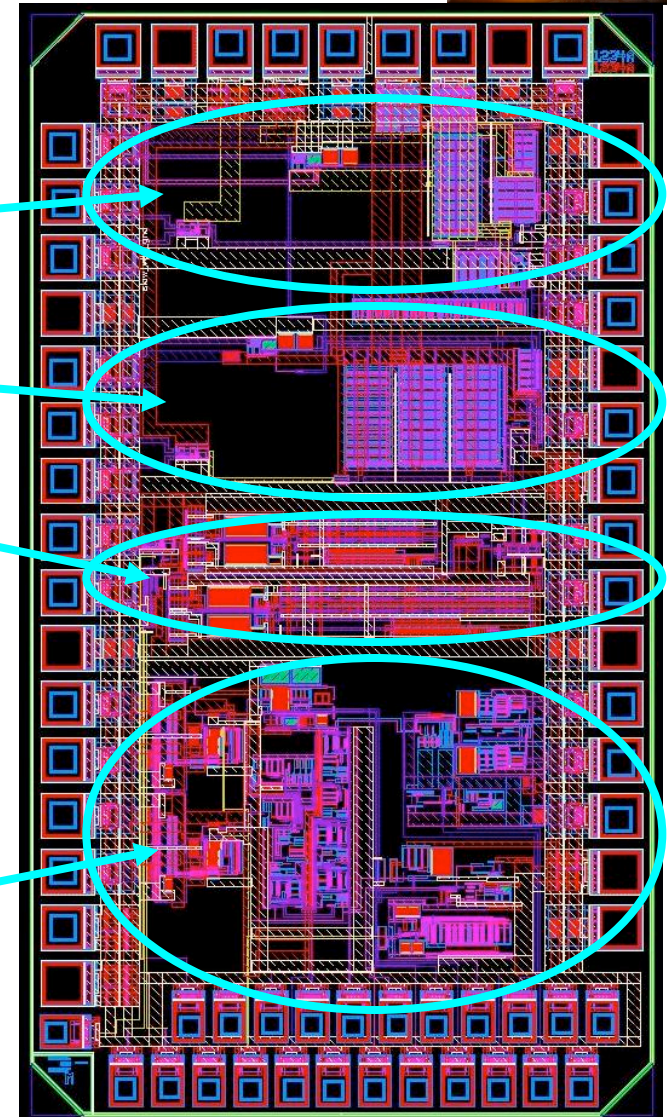
3.2 Gb/s VCSEL Driver

640 MHz clock multipliers  
(4 x 160 and 16 x 40 MHz)

PIN receiver/decoder  
(40, 160, 320 MHz)

2.6 mm

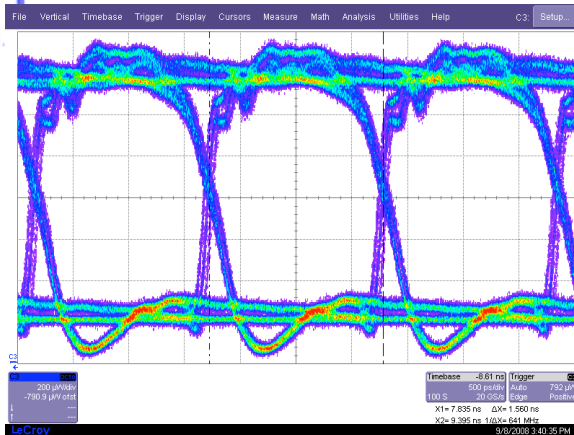
1.5 mm



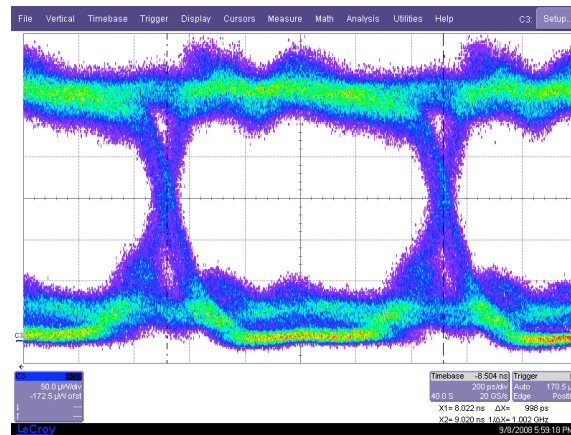




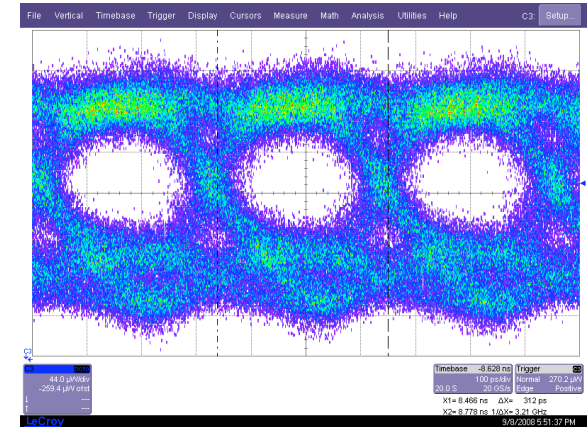
# VCSEL Driver Chip



Slow VDC  
640 Mb/s



Fast VDC  
1 Gb/s



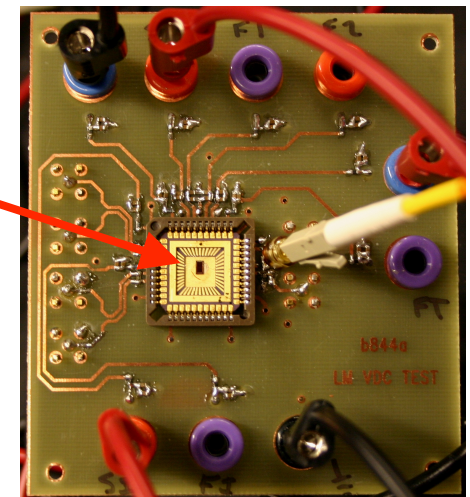
Fast VDC  
3.2 Gb/s

- both chips are working in preliminary study
- LVDS receiver working at high speed
- need detailed study without package

K.K. Gan

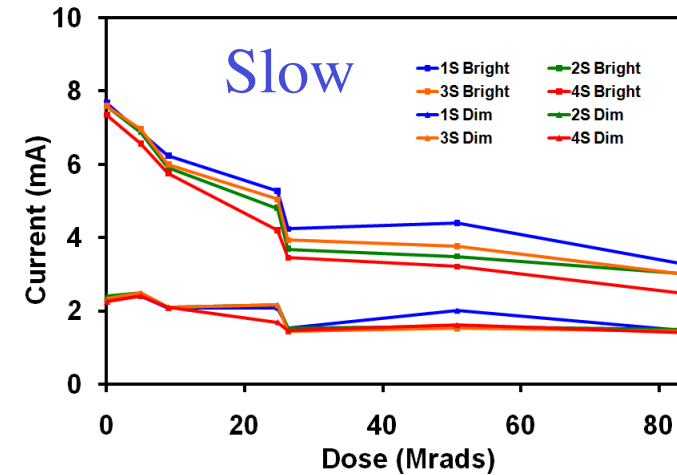
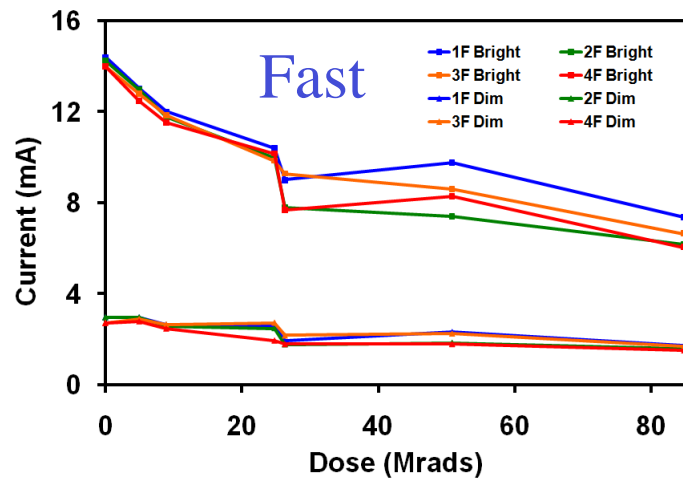
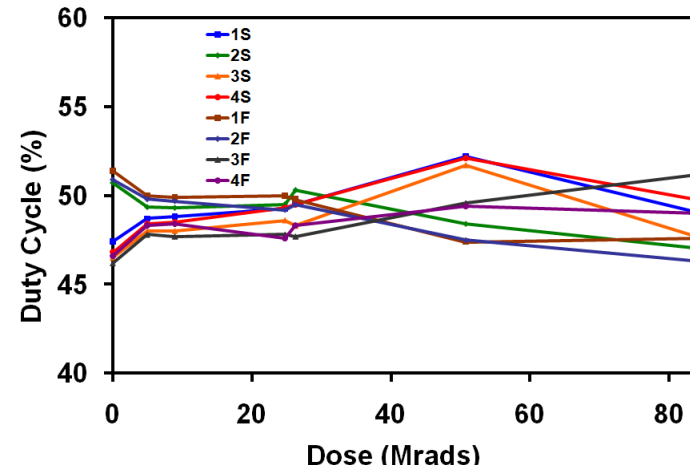
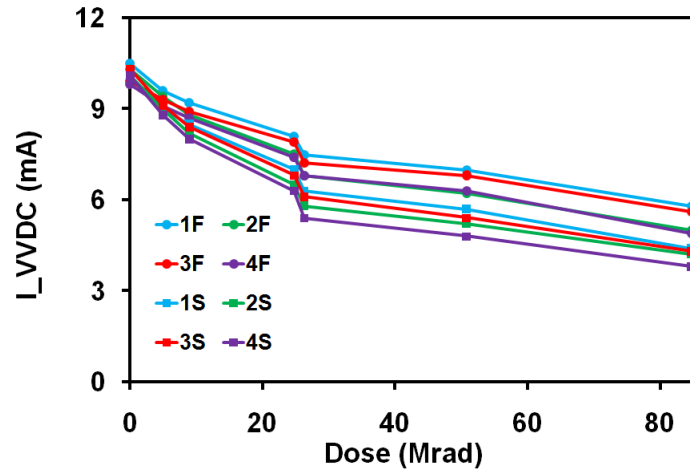
TWEEP08

PLCC  
package





# VDC Irradiation



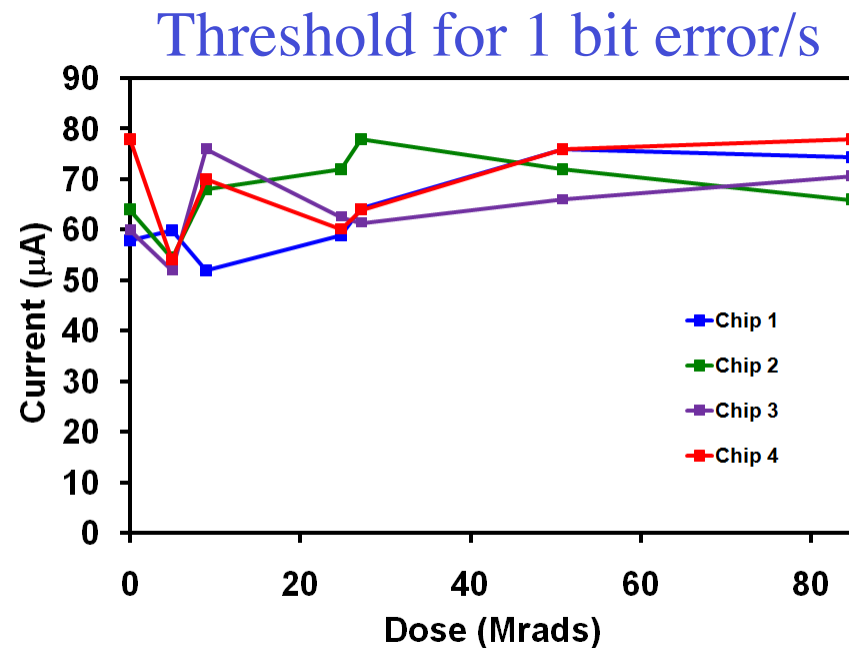
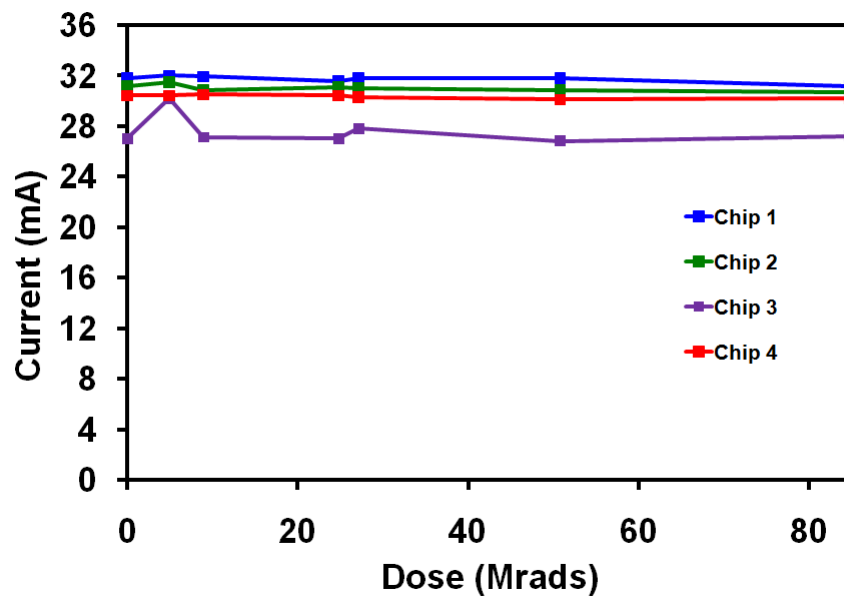
- drive current decreases with radiation for constant ISET
- need detailed study after cool down



# Receiver/Decoder Chip



- Properly decode 40, 80, and 160 Mb/s signals but not 320 Mb/s
  - ◆ LVDS-like output has proper amplitude and baseline
  - ◆ small clock jitter (e.g.  $< 50$  ps @ 160 MHz)
  - ◆ no significant degradation after irradiation

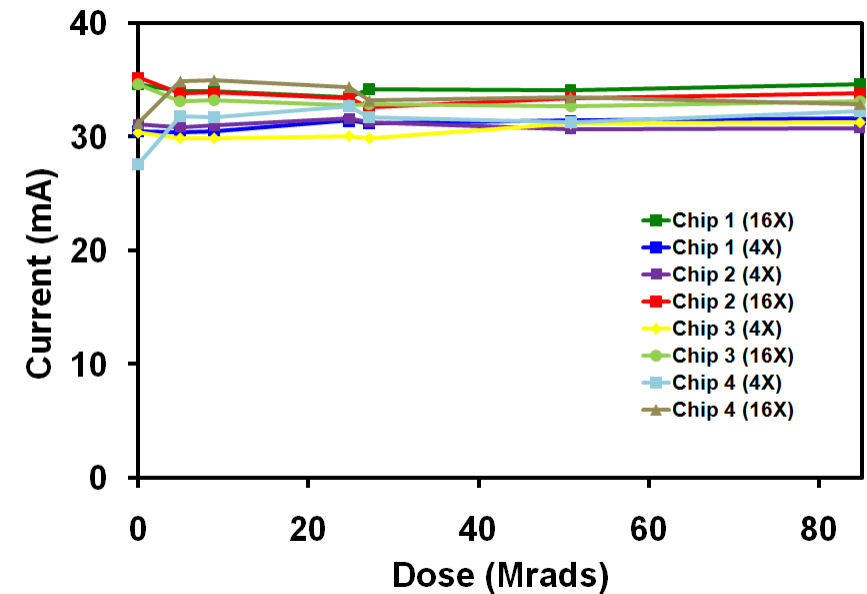
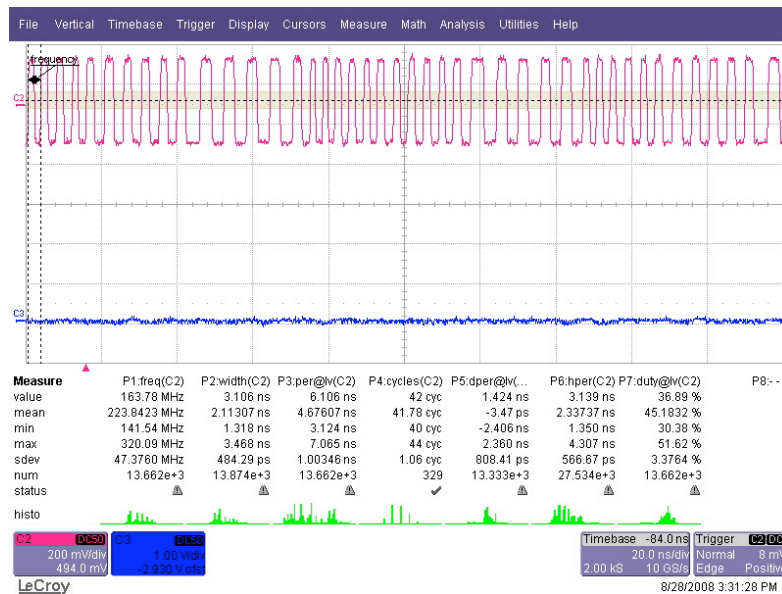




# Clock Multiplier

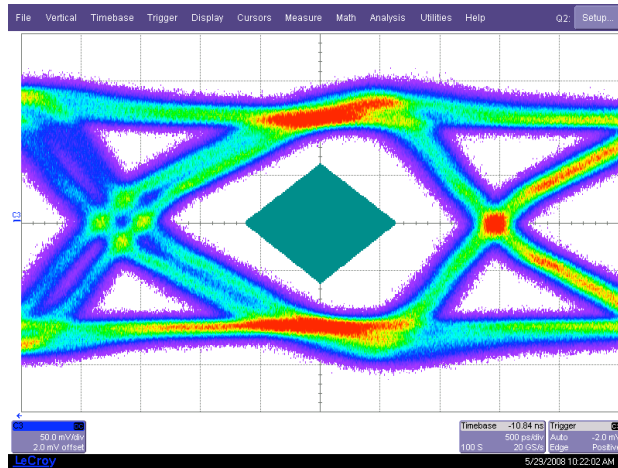


- Both 4 x and 16 x clock multipliers work
  - ◆ clock jitter < 8 ps (0.5%)
  - ◆ two of the four chips lost lock during irradiation
    - need power cycling to resume operation at 640 MHz
  - ◆ no change in current consumption



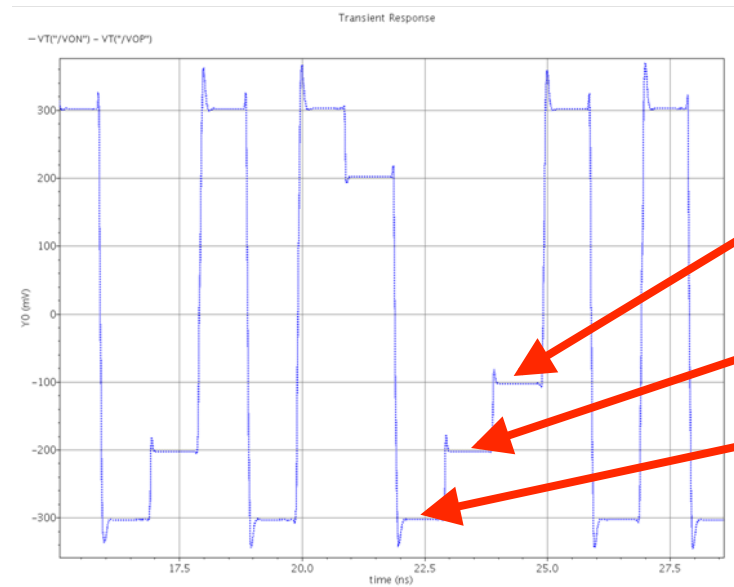


# Skinny Wires with Pre-emphasis



320 Mb/s

4 m



No emphasis

1<sup>st</sup> tap emphasis

2<sup>nd</sup> tap emphasis

- Signals from modules (320 Mb/s) can be transmitted up to ~ 4 m with pre-emphasis
  - ◆ minimum material
  - ◆ allow serializer chip to be placed further from the IP to reduce SEU



# Summary

- Good PIN candidates identified
- Good VCSEL candidates identified
- First 0.13  $\mu\text{m}$  submission mostly successful
  - ◆ full characterization of pre/post irradiation in progress
  - ◆ aim for next iteration in winter 2009