New Results on Opto-Electronics

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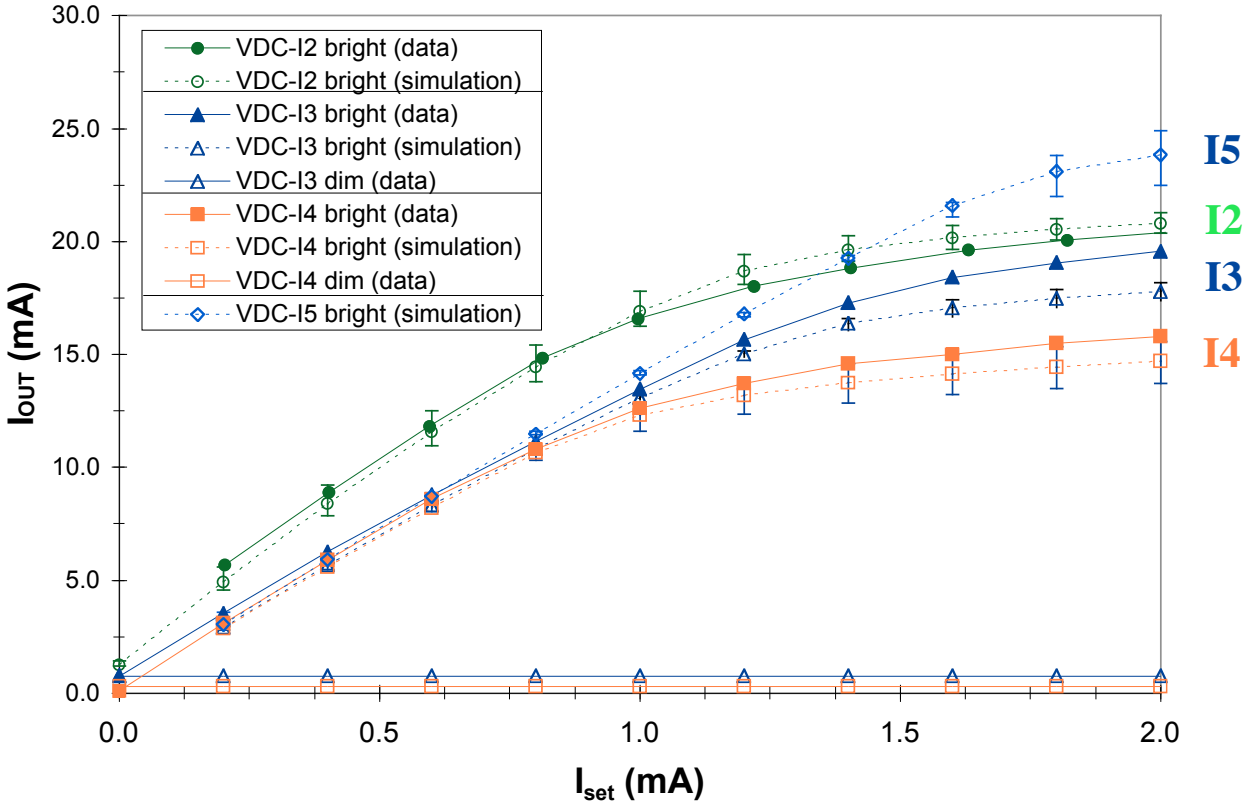
Outline

- Results on VDC/DORIC-I4
- Results on Irradiation
- Light Budget
- Improvements in VDC/DORIC-I5
- Summary

Opto-electronics Team

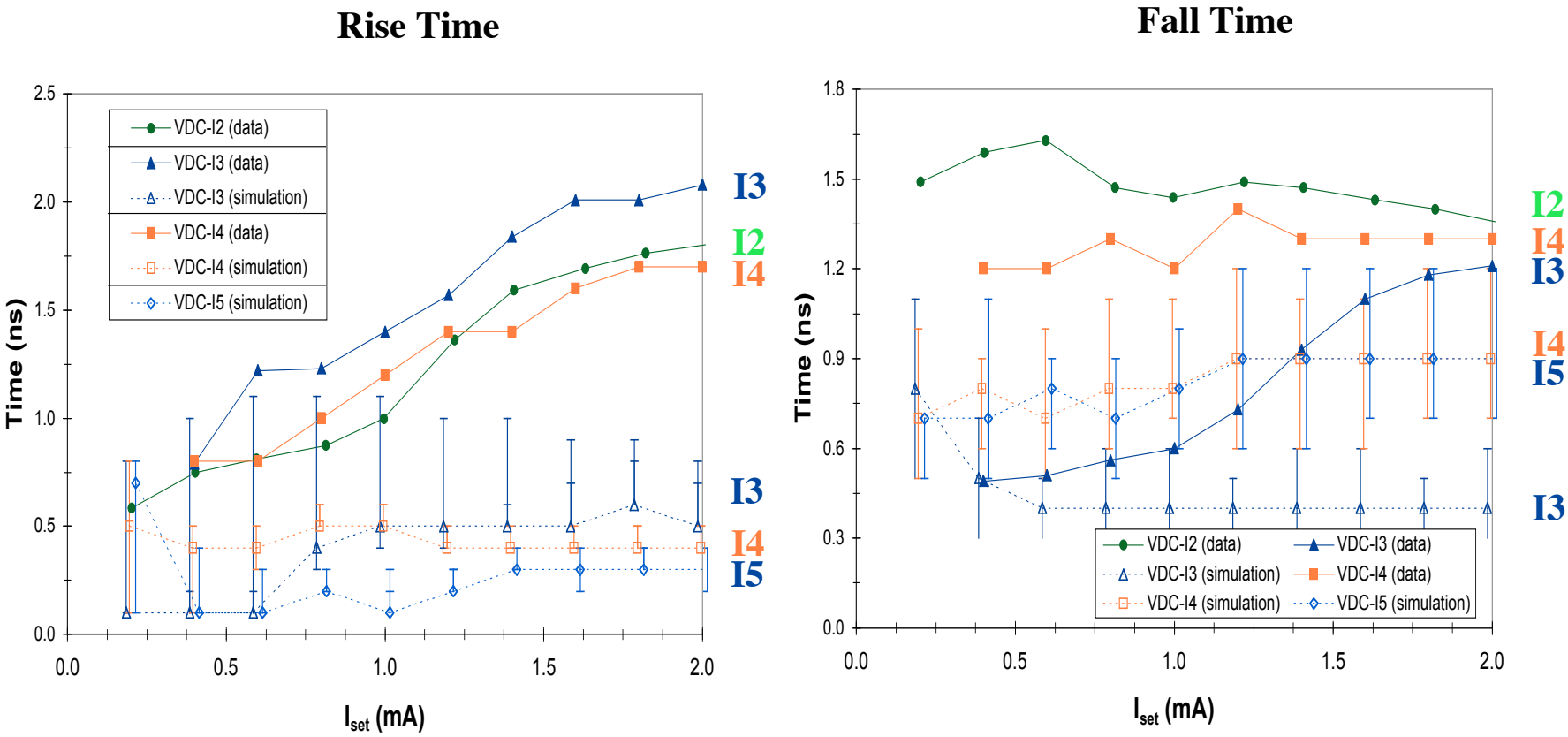
- The Ohio State University:
  - Kregg Arms, K.K. Gan, Mark Johnson, Harris Kagan, Richard Kass, Chuck Rush, Rouben Ter-Antonian, Michael Zoeller
- Siegen University:
  - Alex Ciliox, Martin Holder, Michal Ziolkowski

VDC-I4: VCSEL Drive Currents vs I_{set}



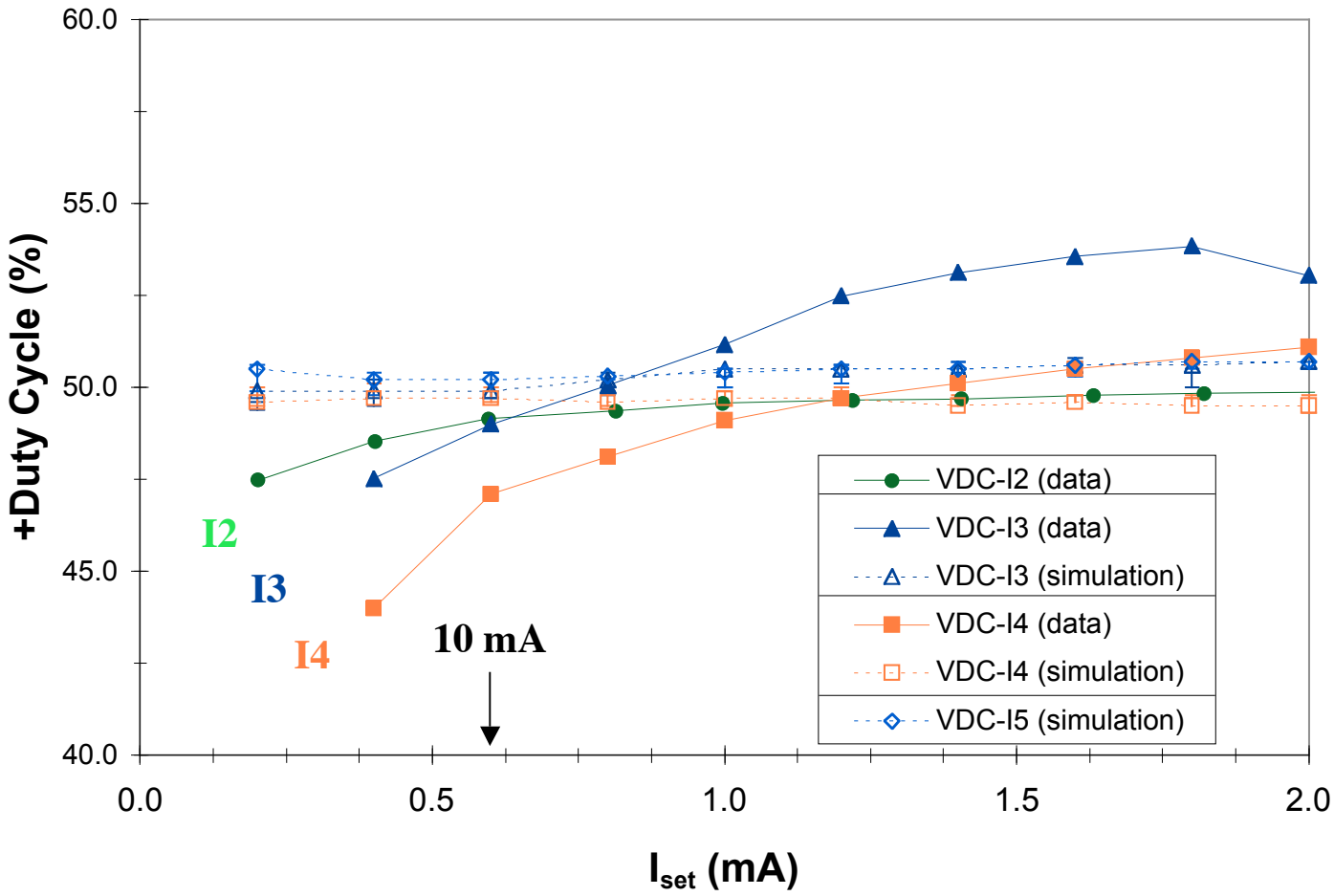
- turning over at high I_{set} is due to 10 Ω in series used in measurement
- dependence of bright current vs I_{set} is as expected
- bright and dim currents of VDC-I4 are somewhat low
- VDC-I5 is predicted to produce more currents

Rise/Fall Time vs I_{set} for 40 MHz Clock



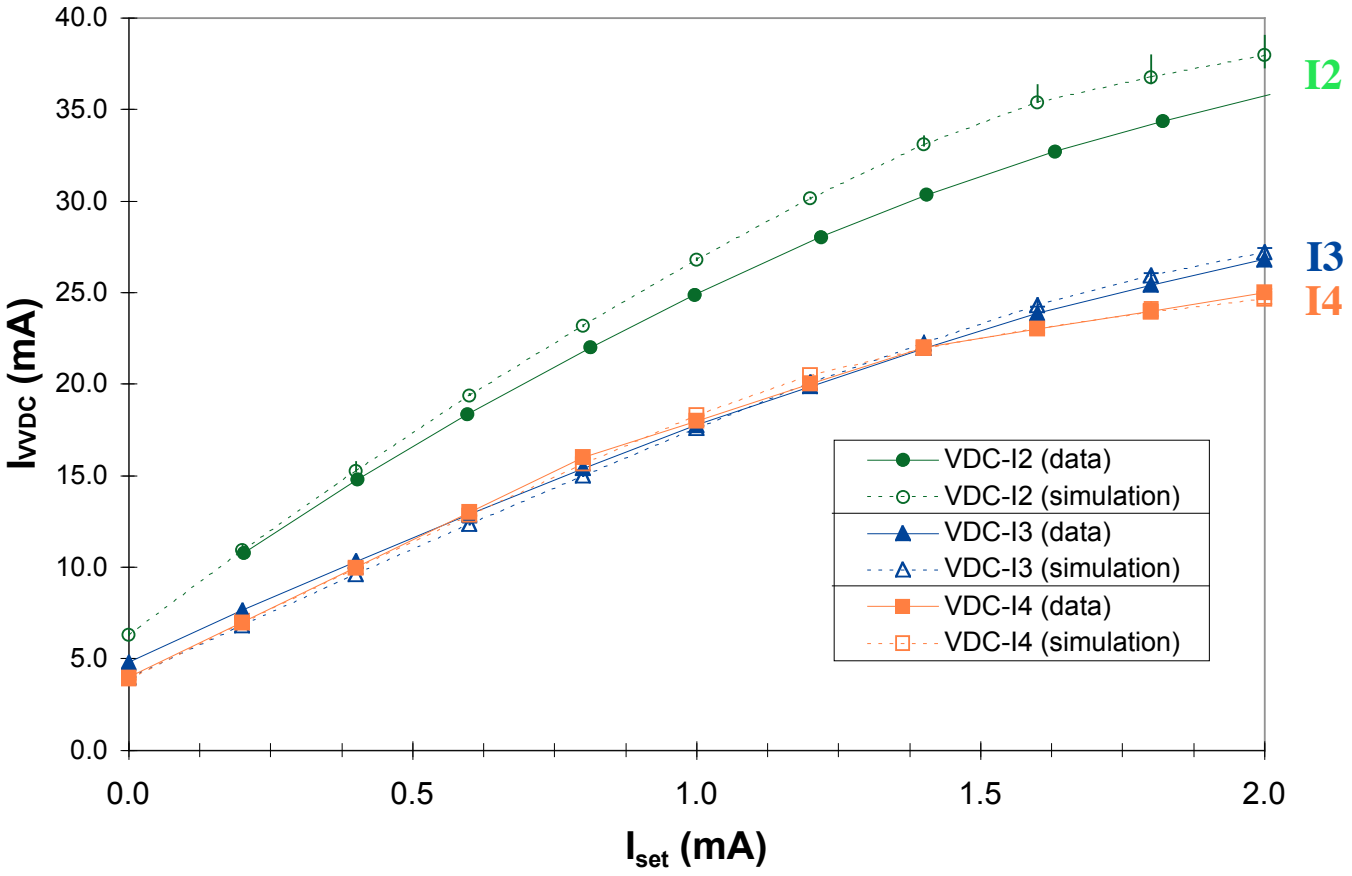
- rise/fall times slower than predictions
- underestimate of package stray capacitance?

Duty Cycle vs I_{set} for 40 MHz Clock



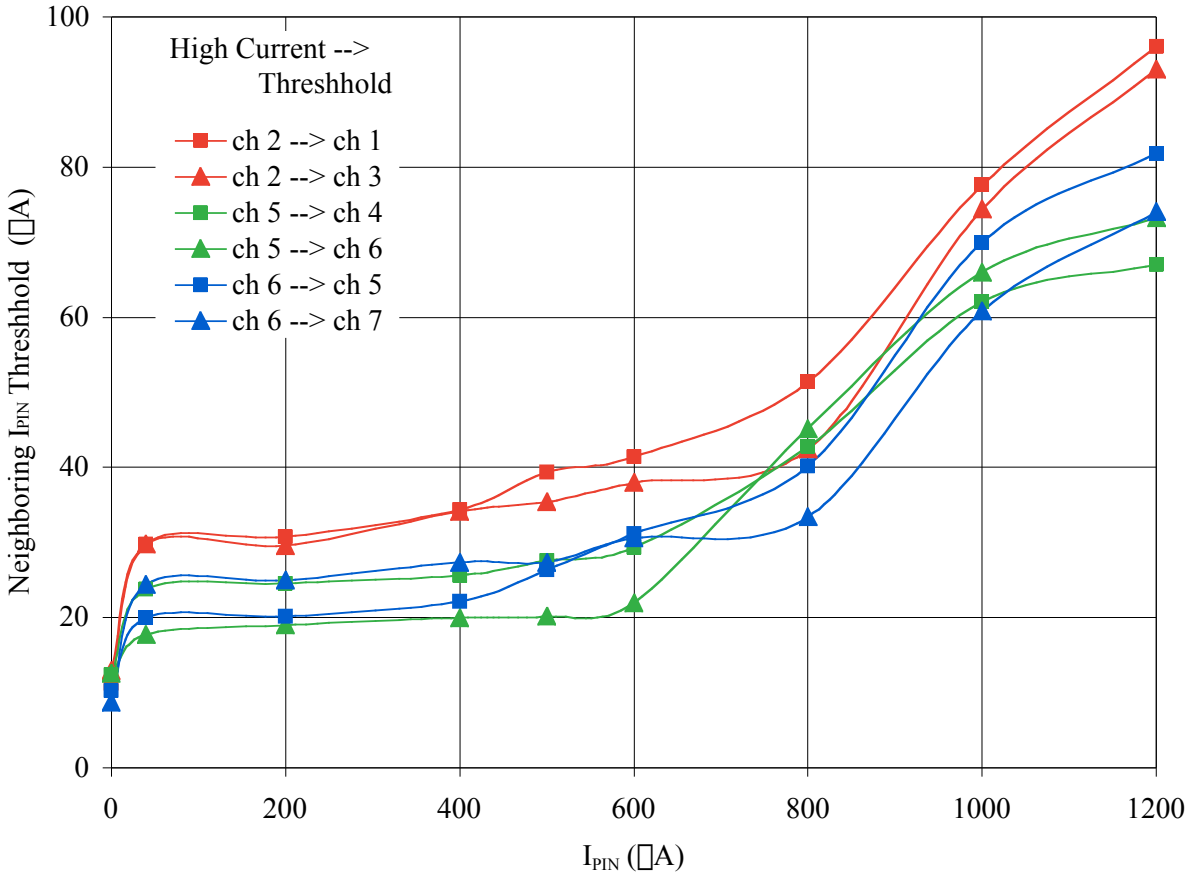
- clock duty cycle close to 50%

Current Consumption of VDC-I4



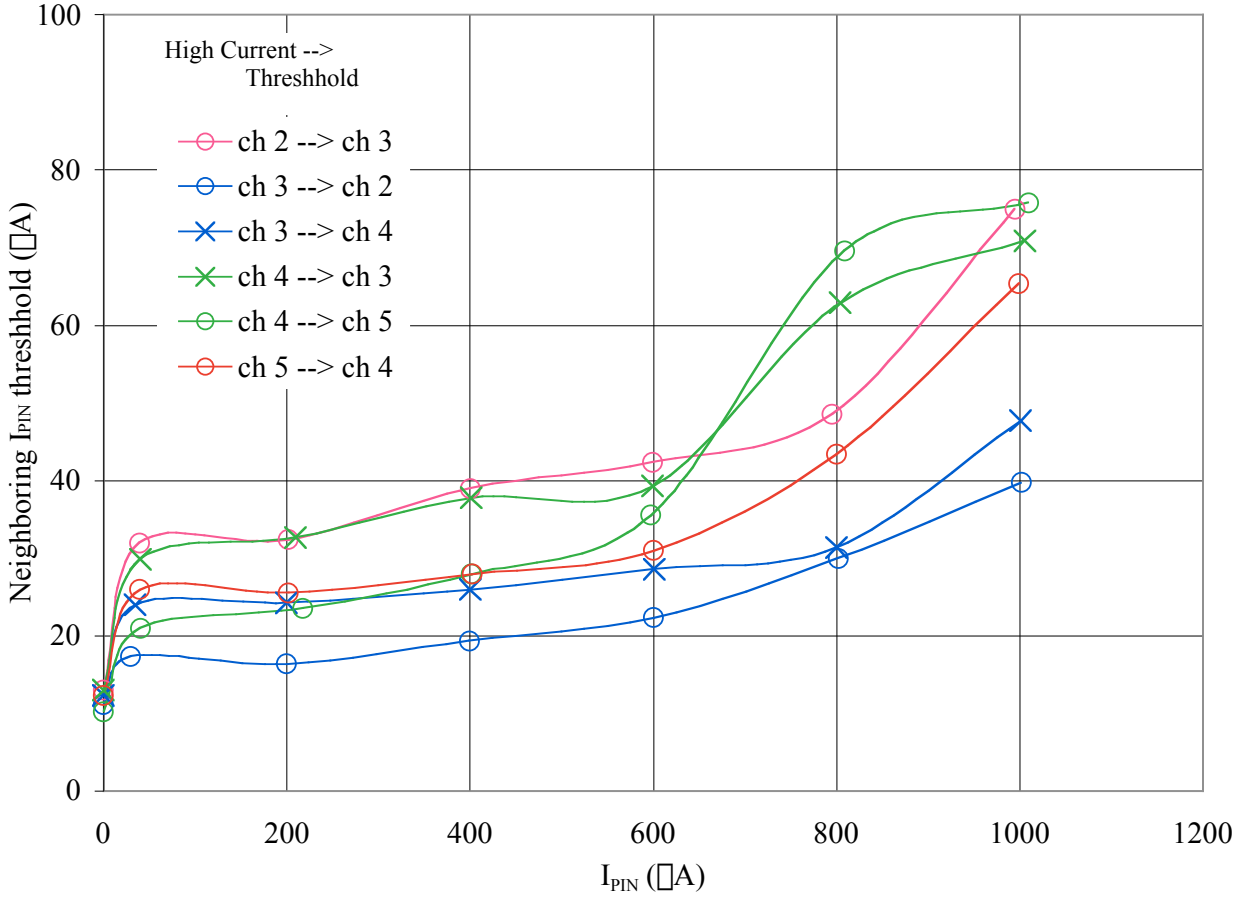
- VDC-I4 current consumption is consistent with expectation

PIN Current Thresholds in DORIC-I4



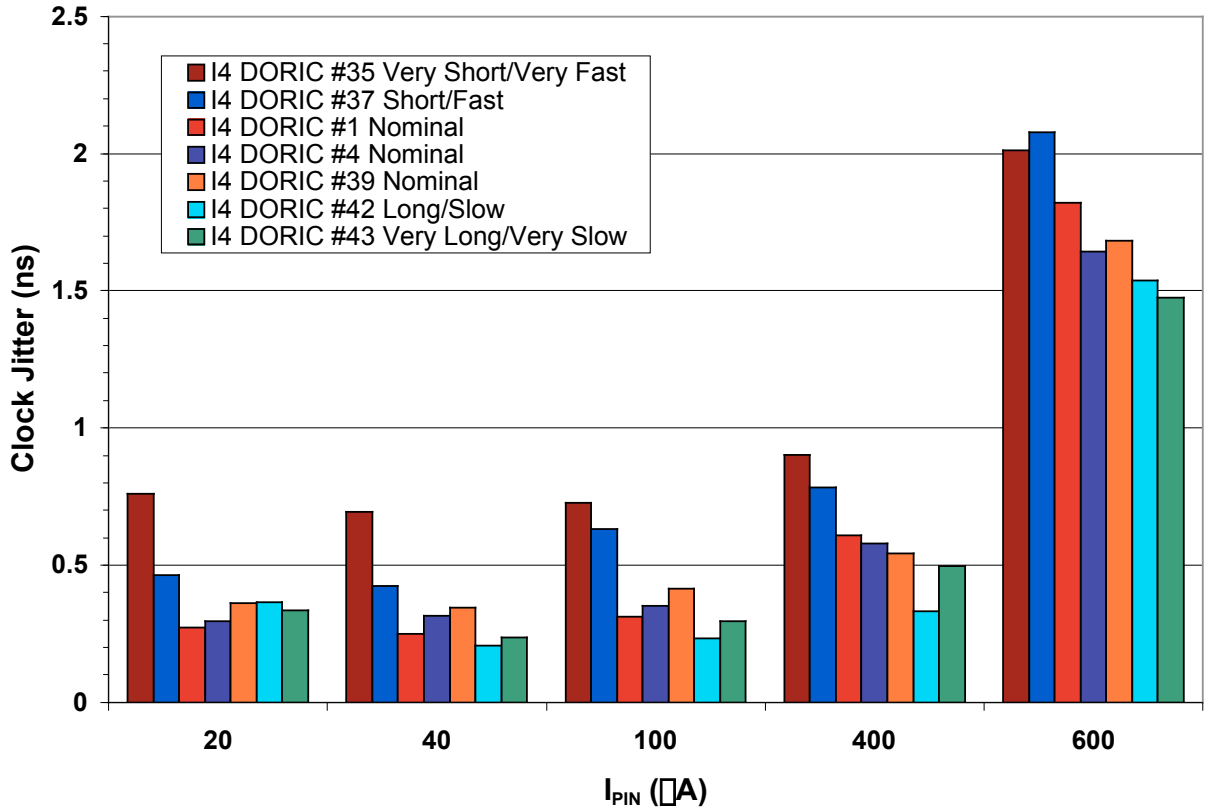
- PIN current thresholds for no bit error are low
- active link increases thresholds of neighboring channels

PIN Current Thresholds in DORIC-I4



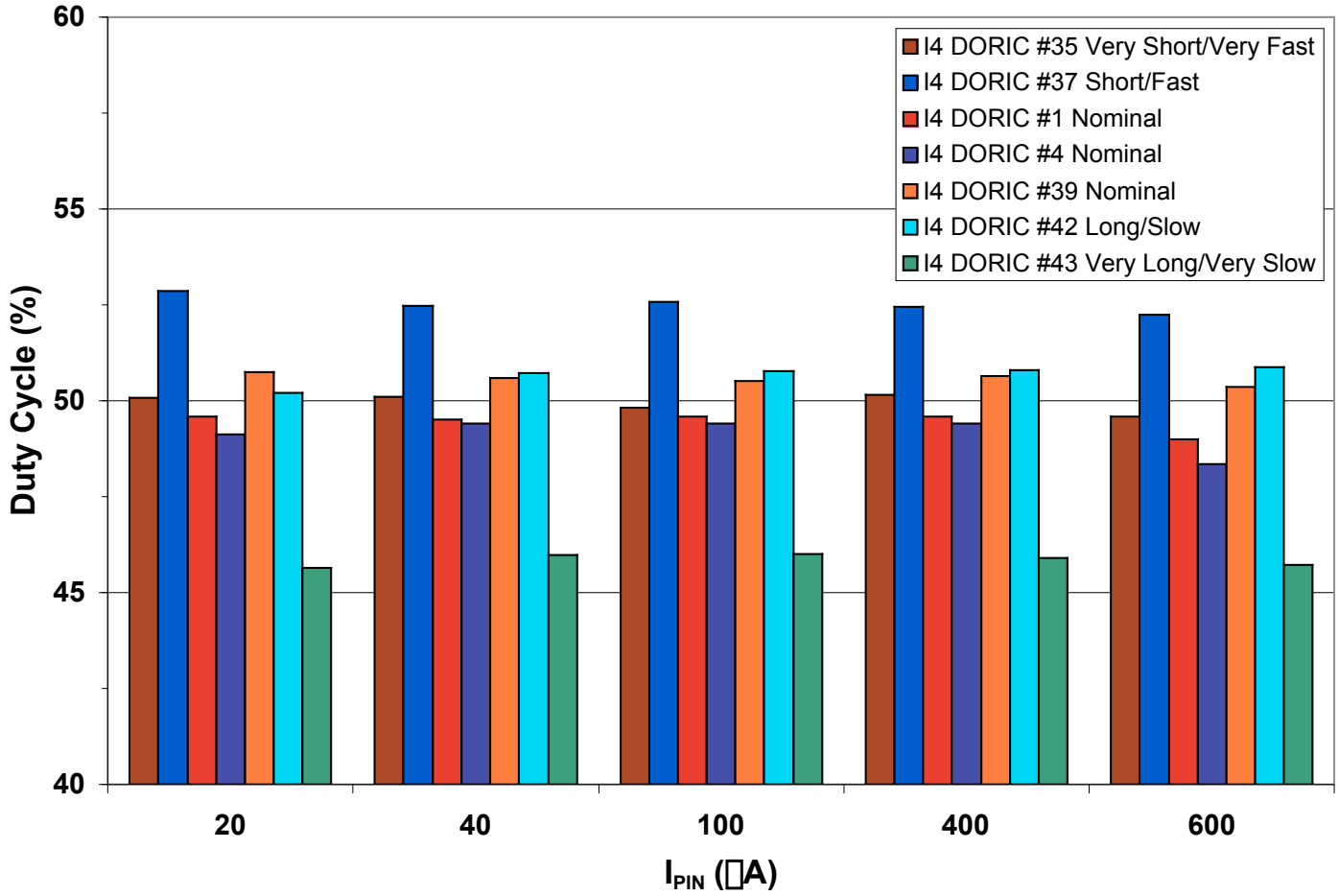
- similar cross talk between channels in same and separate chips
- cross talk from adjacent PIN channels?

Jitter of Recovered Clock in DORIC-I4



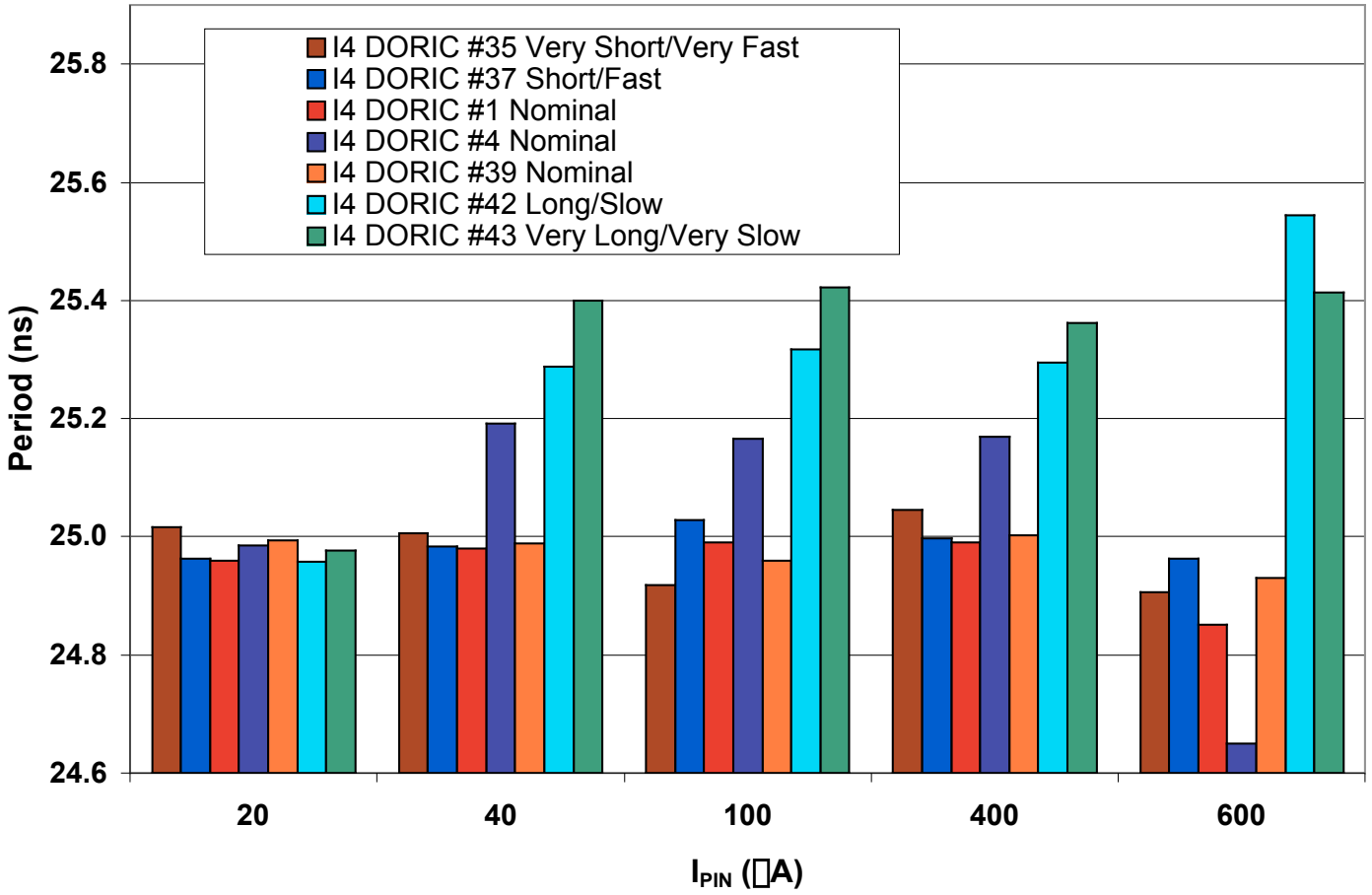
- jitter is low for low PIN current
- jitter is large for high PIN current due to kludge used in getting DORIC to work with common cathode PIN

Duty Cycle of Recovered Clock in DORIC-I4



- duty cycle is close to 50%

Period of Recovered Clock in DORIC-I4

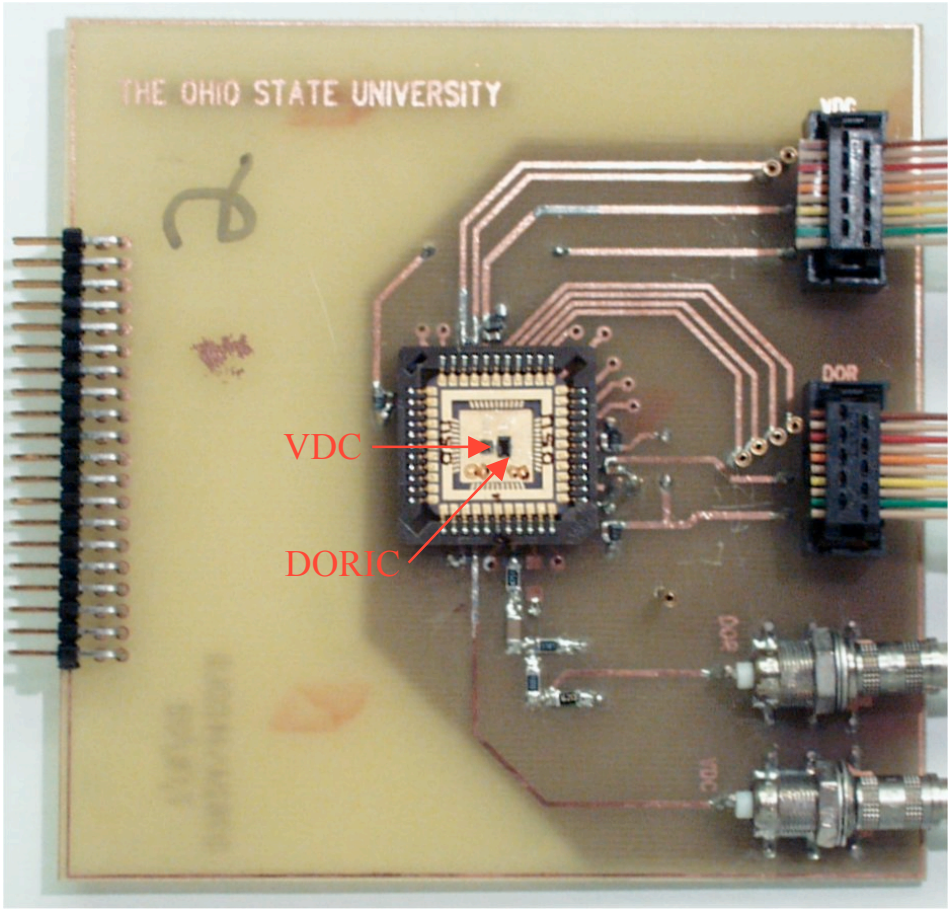


- clock period is very close to 25 ns

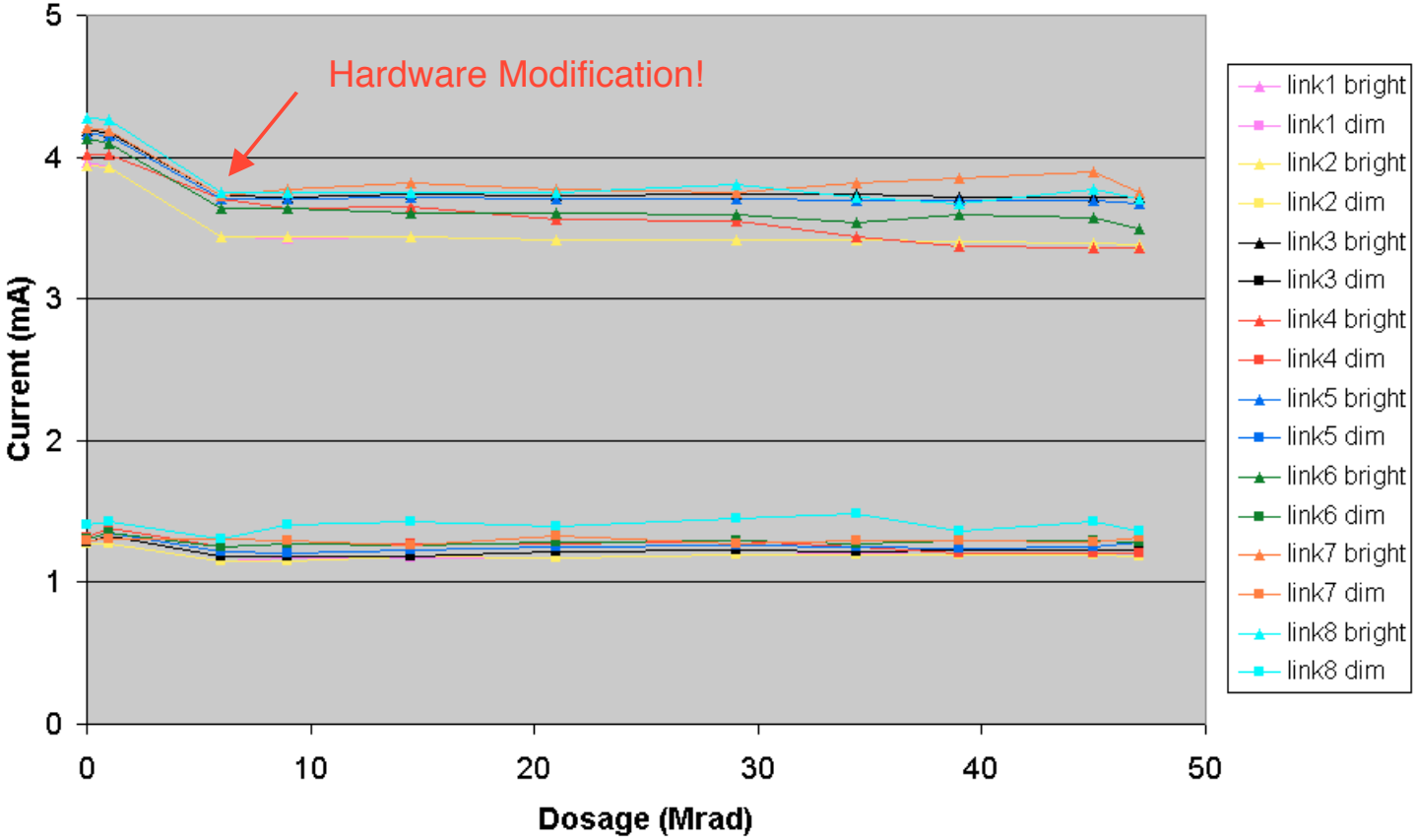
Proton Irradiation at CERN

- use 24 GeV protons at T7
- cold box: purely electrical testing
  - cold box I:
    - 1.8 x 10^{15} proton/cm^2 or 54 Mrad
    - 8 VDC/DORIC-I4
  - cold box II:
    - 1.0 x 10^{15} proton/cm^2 or 30 Mrad
    - 2 VDC/DORIC-I4, 6 VDC/DORIC-I3
- shuttle: opto-link testing
  - opto-board I: 5 working clock and data links
  - opto-board II: 4 working data links
  - opto-board III: 1 and 6 working clock and data links

Cold Box Test Card

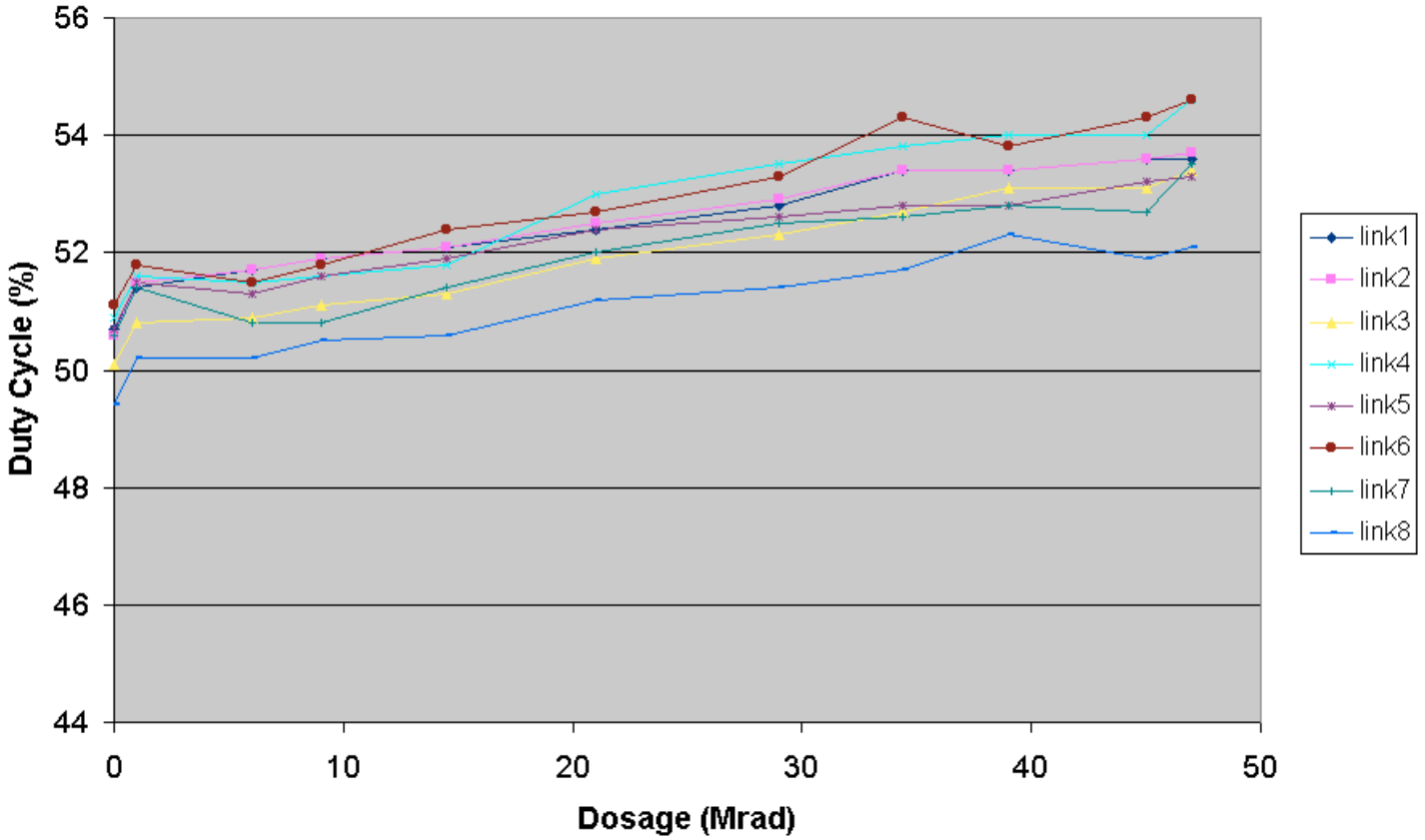


VDC-I4: VCSEL Current vs. Dosage



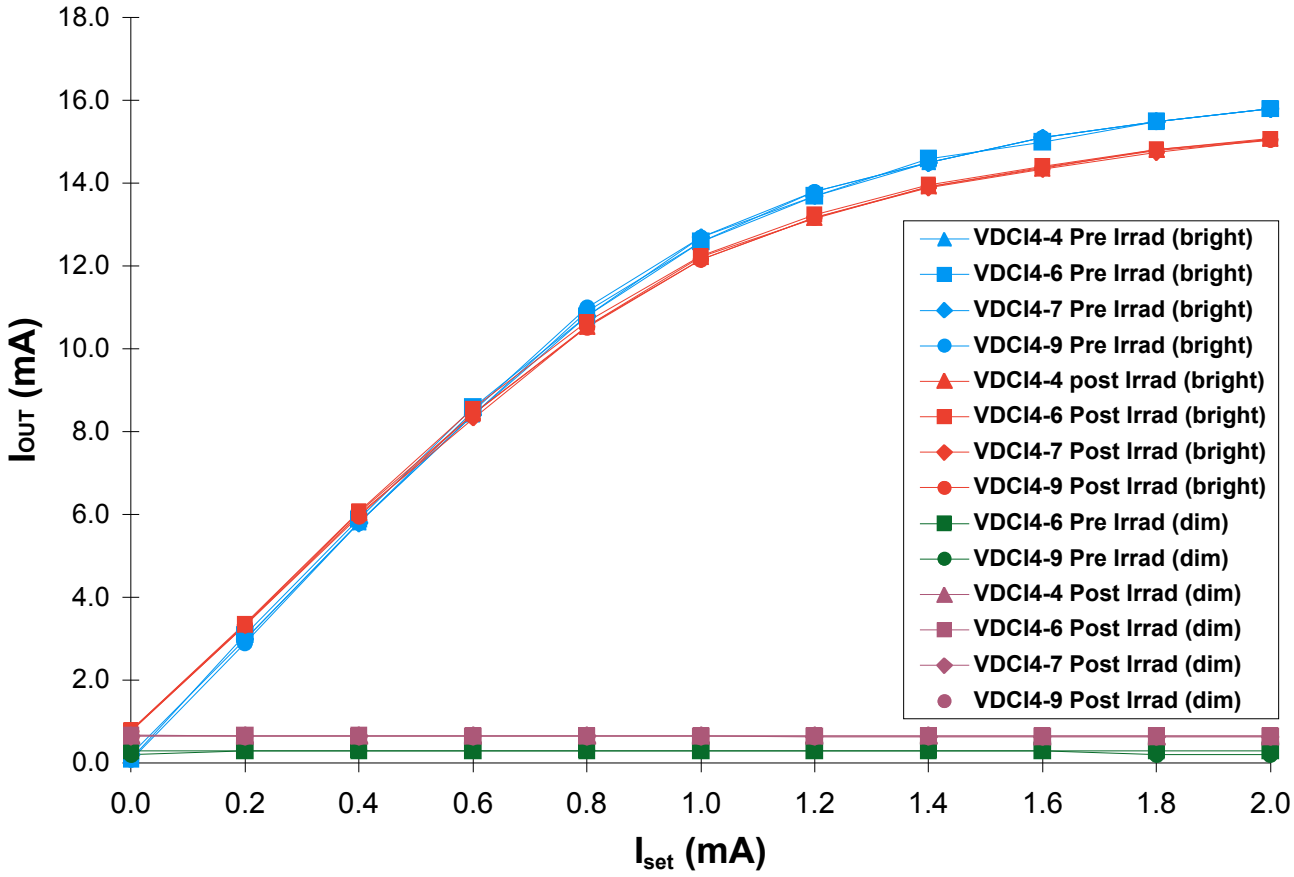
- bright & dim currents remain constant up to 45 Mrad

VDC-I4: Clock Duty Cycle vs. Dosage



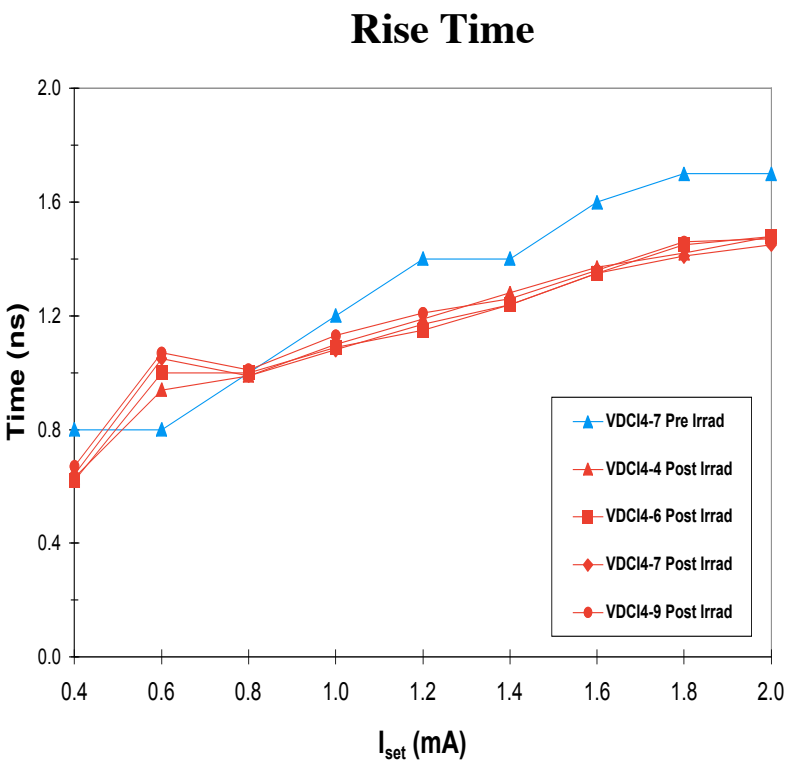
- duty cycle increases by ~ 2% after 45 Mrad

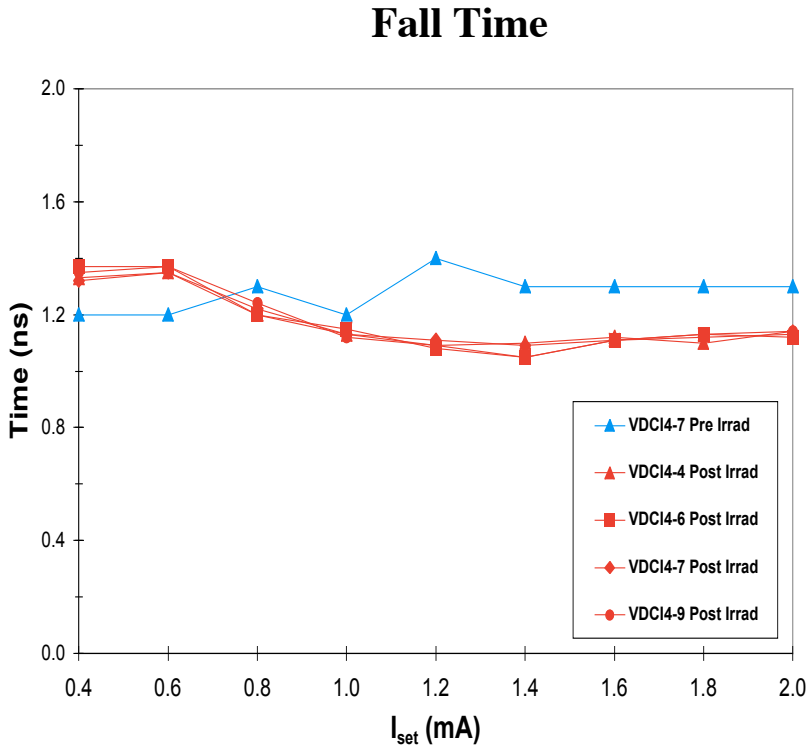
VCSEL Drive Current of Irradiated VDC-I4



- no degradation from irradiation
- similar result for irradiated VDC-I3

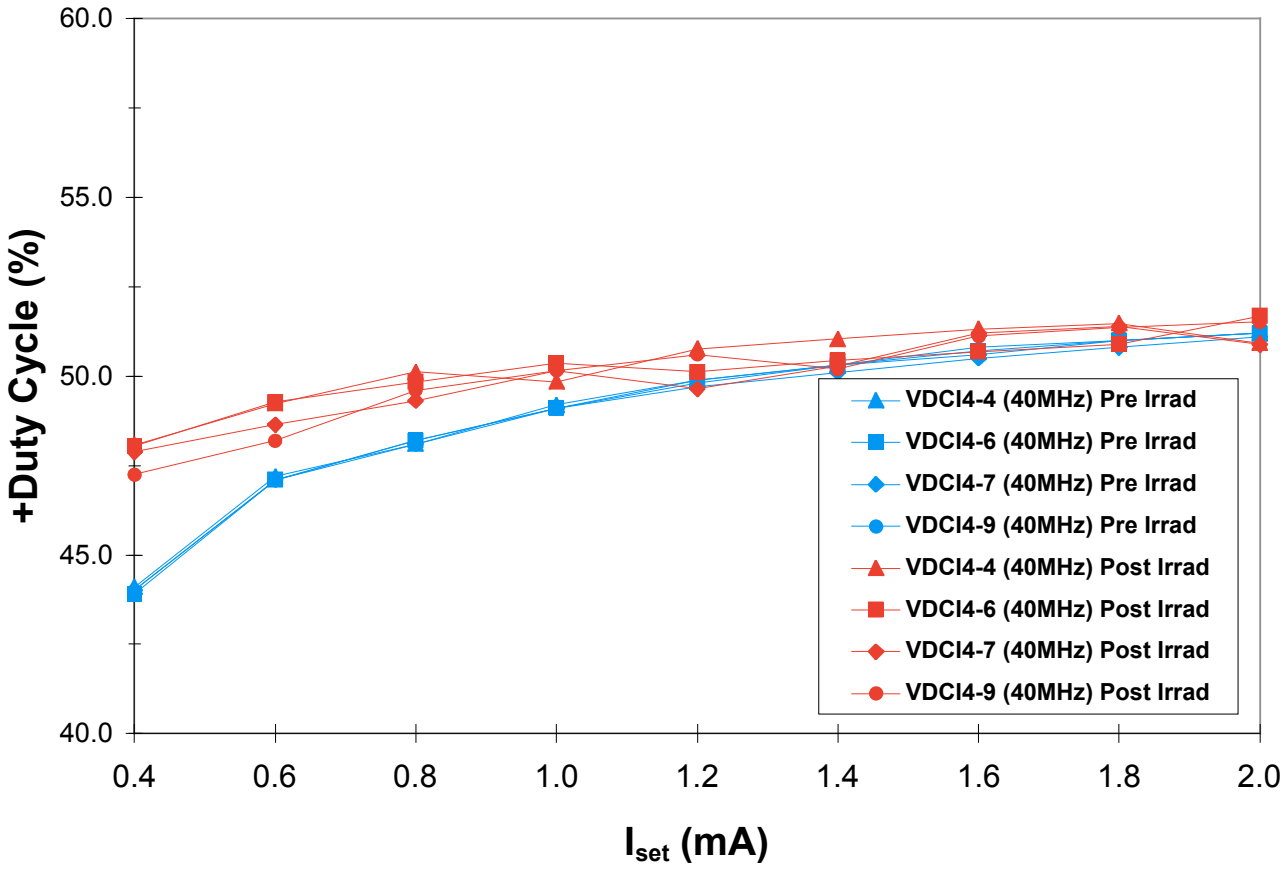
Rise/Fall Time of Irradiated VDC-I4





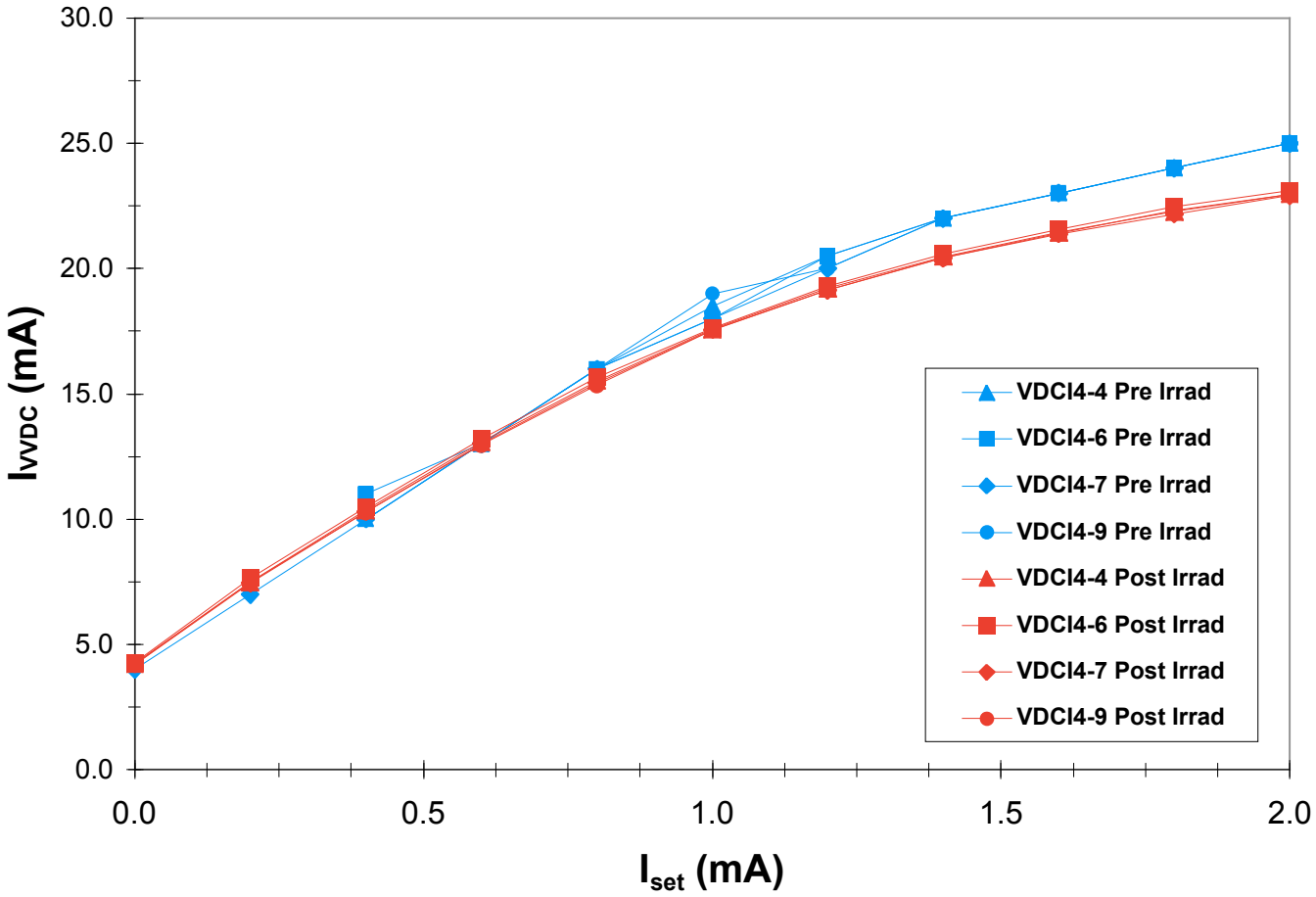
- no degradation from irradiation
- similar result for irradiated VDC-I3

Clock Duty Cycle of Irradiated VDC-I4



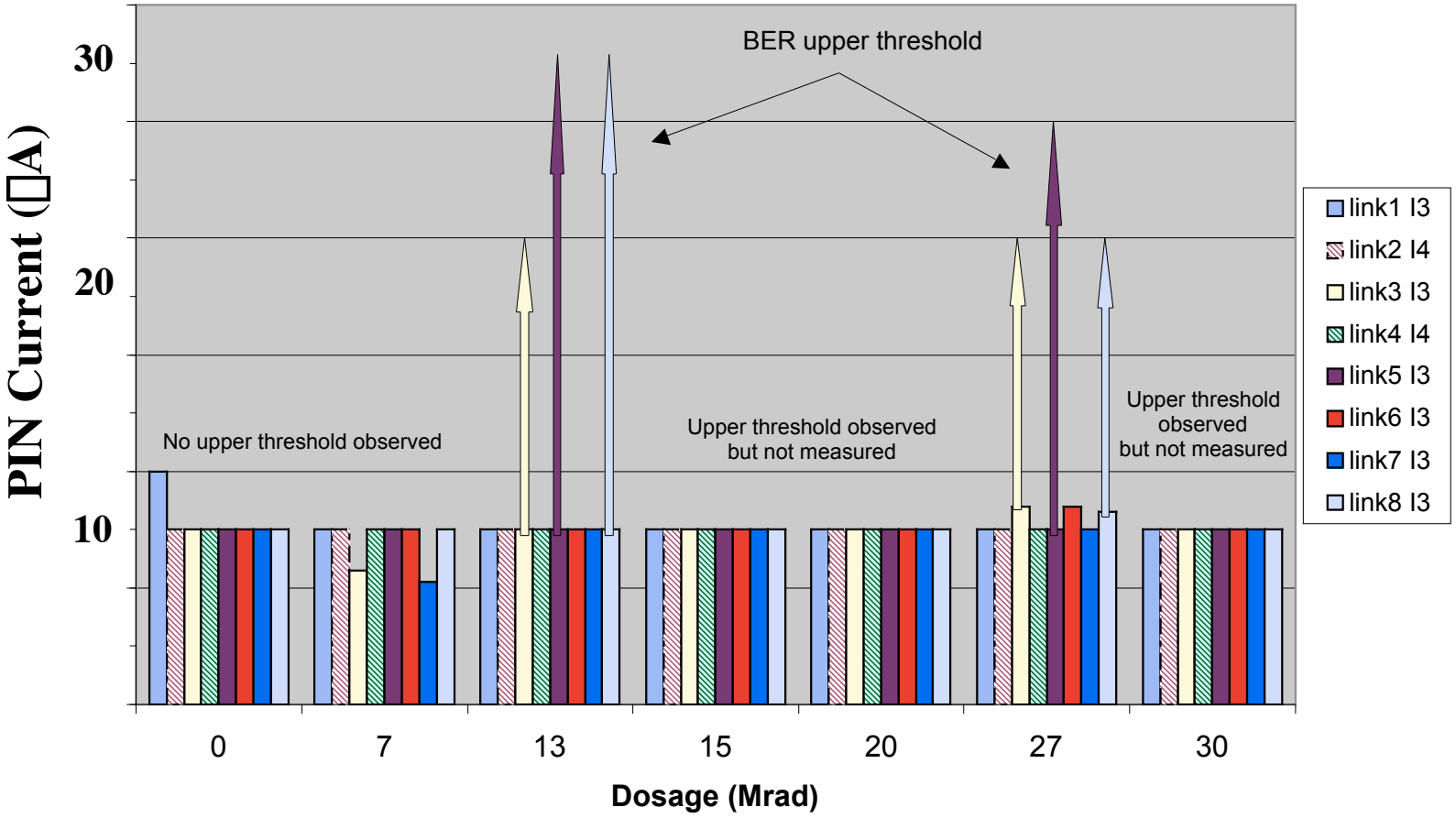
- no degradation from irradiation
- similar result for irradiated VDC-I3

Current Consumption of Irradiated VDC-I4



- no increase in current consumption after irradiation
- similar result for irradiated VDC-I3

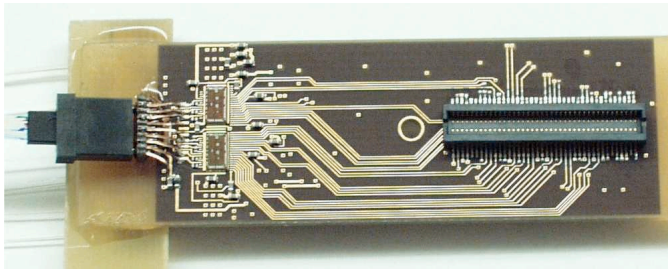
Bit Error Thresholds for DORIC-I3/I4



- low PIN current thresholds remain constant up to 30 Mrad
- 3 DORIC-I3 have small upper thresholds after 13 Mrad

Test Boards for Irradiation in Shuttle

Opto-board with 7 opto-links

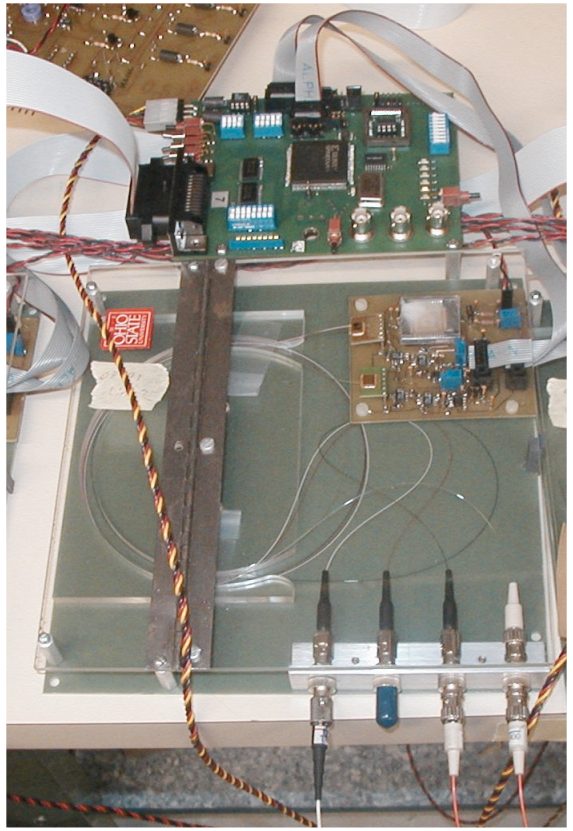


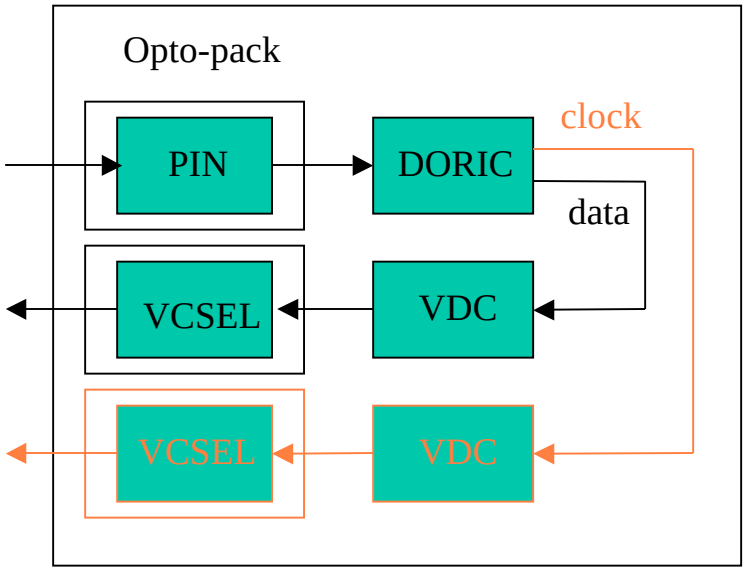
Bi-phase marked optical signal

25 m fibers/wires

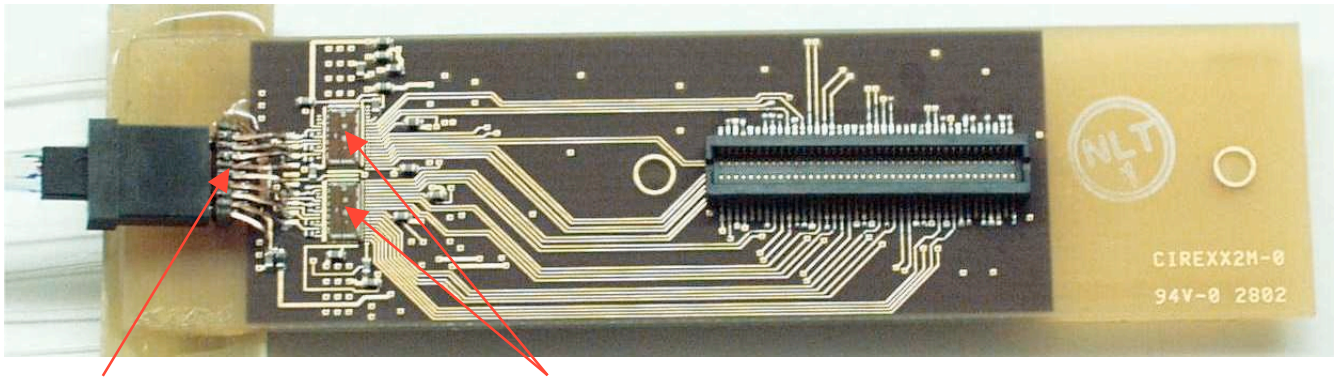
Decoded data

Bit error test boards in control room (one per opto-link)

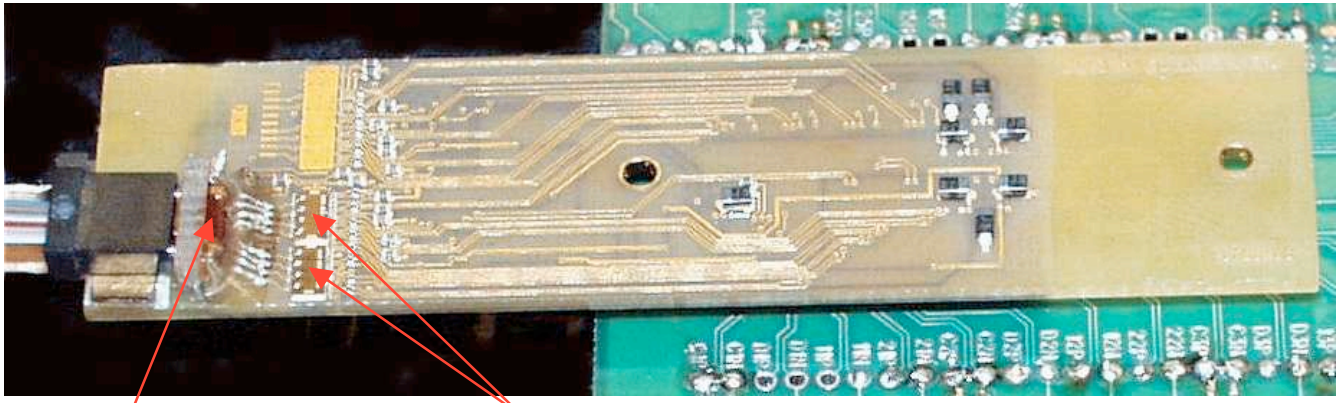




Opto-Board for Irradiation Study

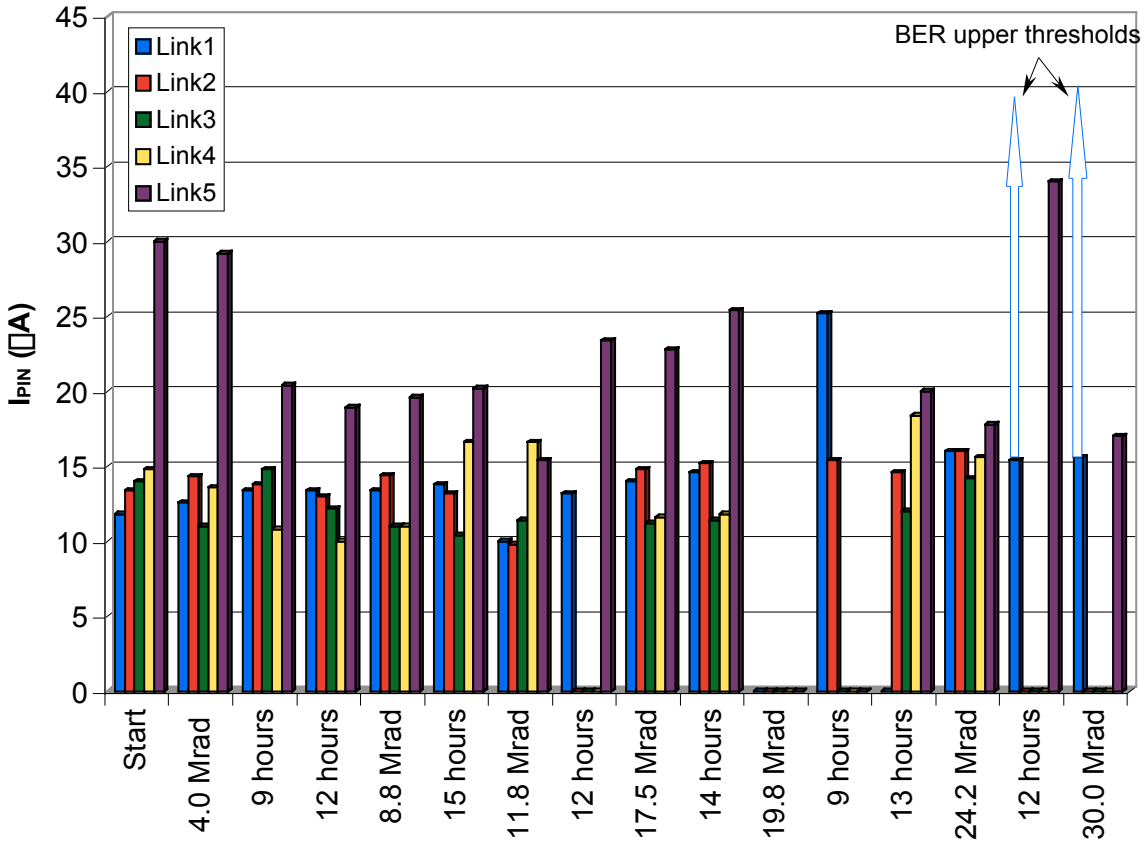


PIN array 4-channel DORIC-I4



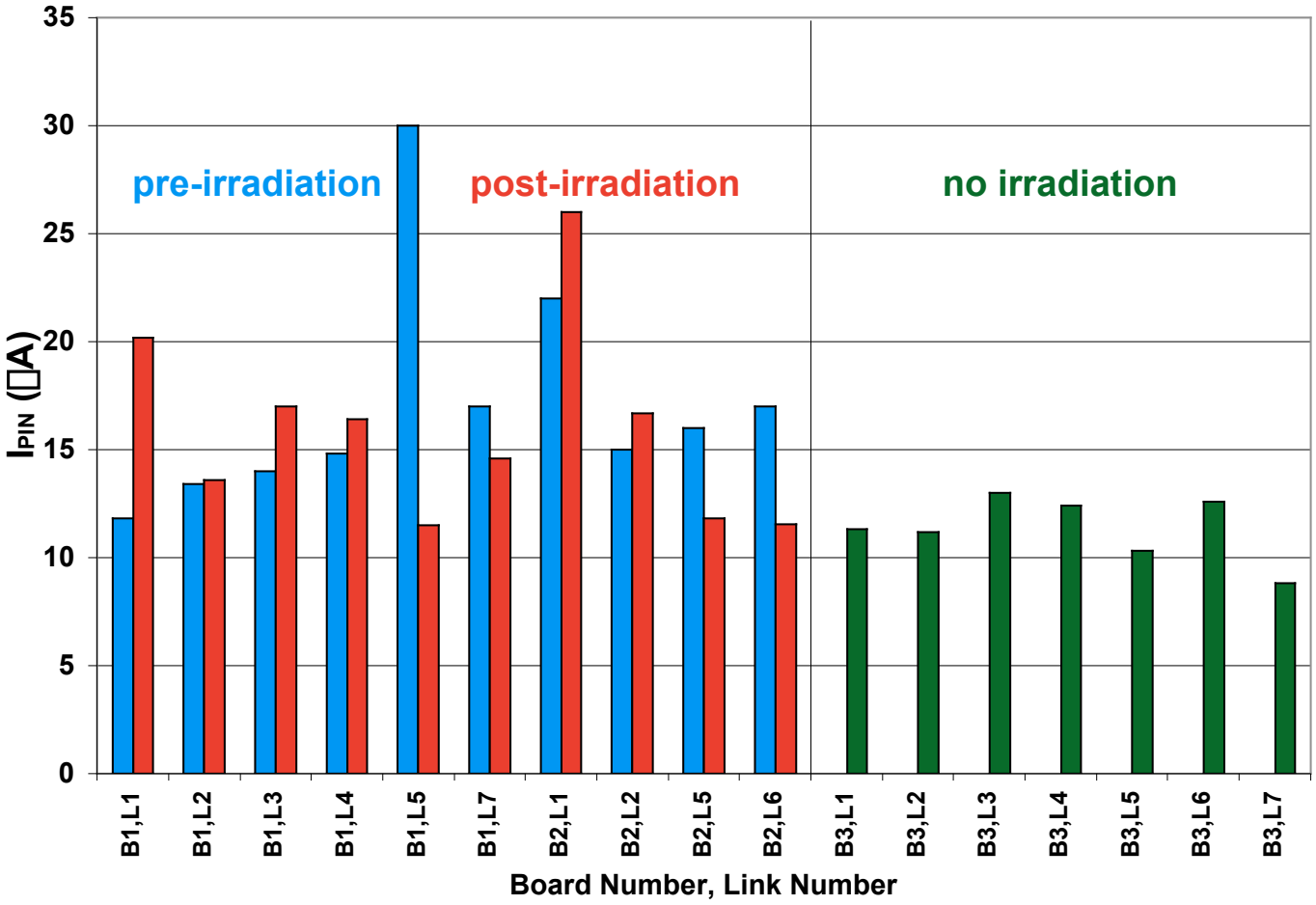
VCSEL array 4-channel VDC-I4

Opto-Board I: Bit Error Thresholds vs. Dosage



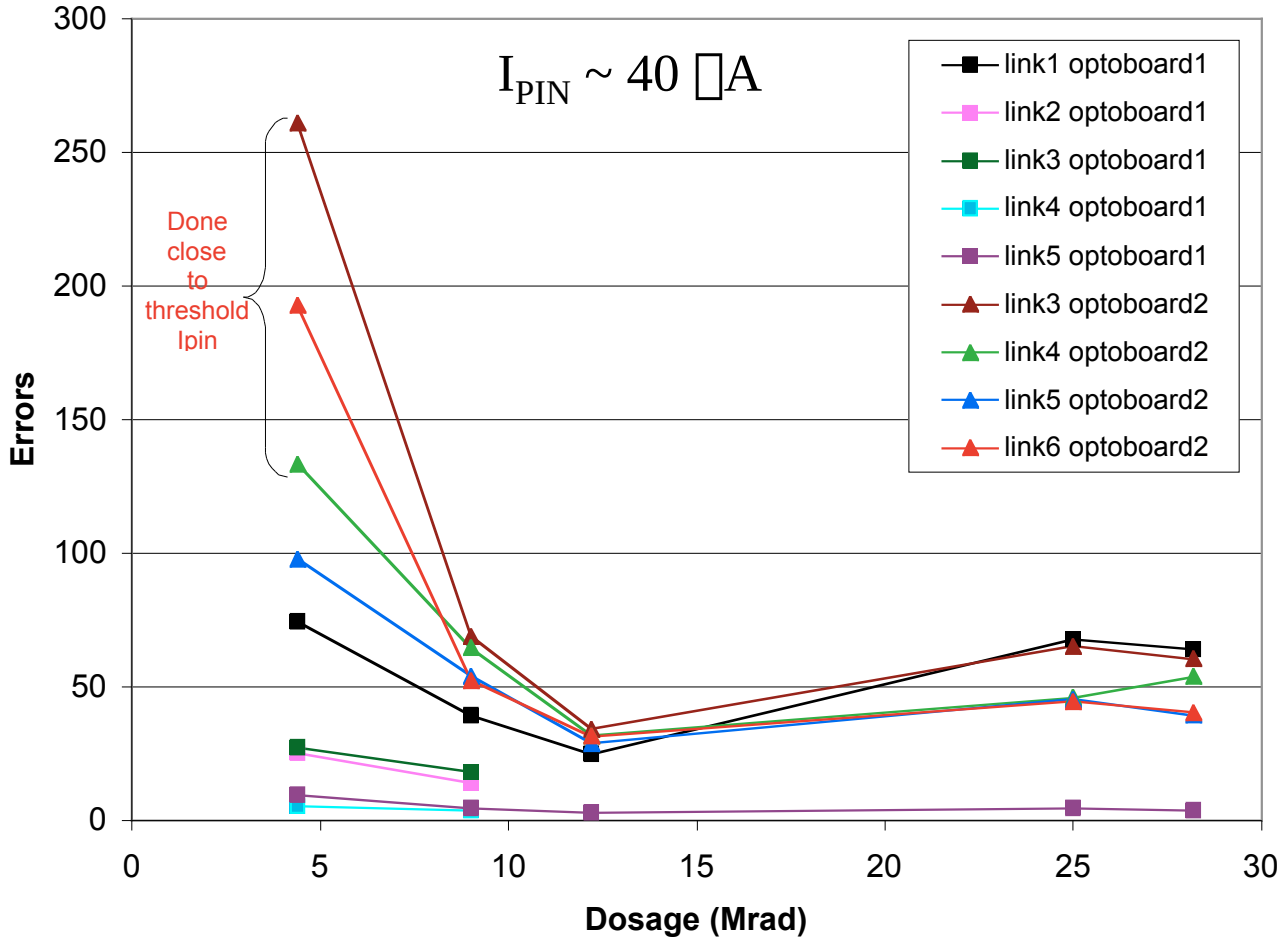
- bit error thresholds remain constant up to 30 Mrad
- one link has low upper threshold at ~ 30 Mrad
  - post-irradiation upper threshold ~ 640 □A

Pre/Post-Irradiation Bit Error Thresholds



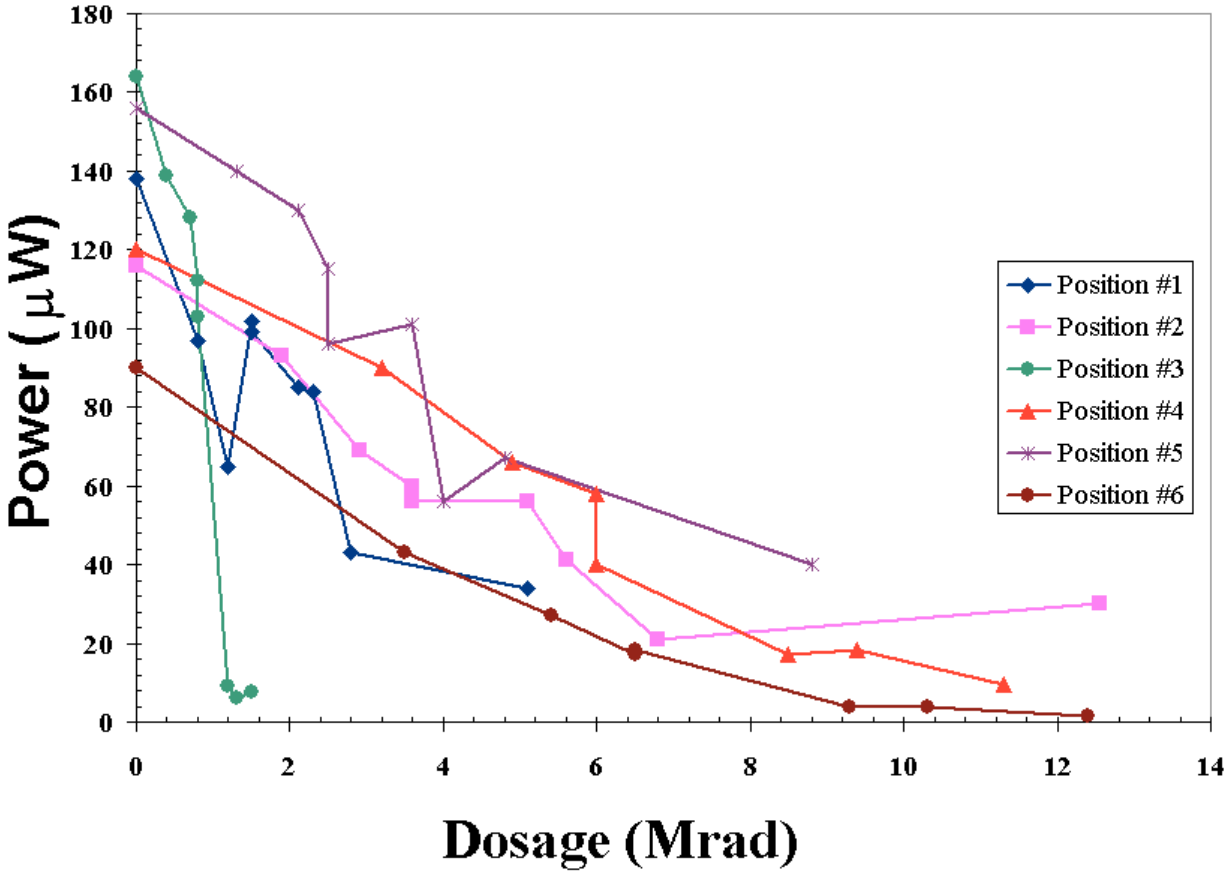
- no degradation from irradiation

Errors during Spill on Opto-links

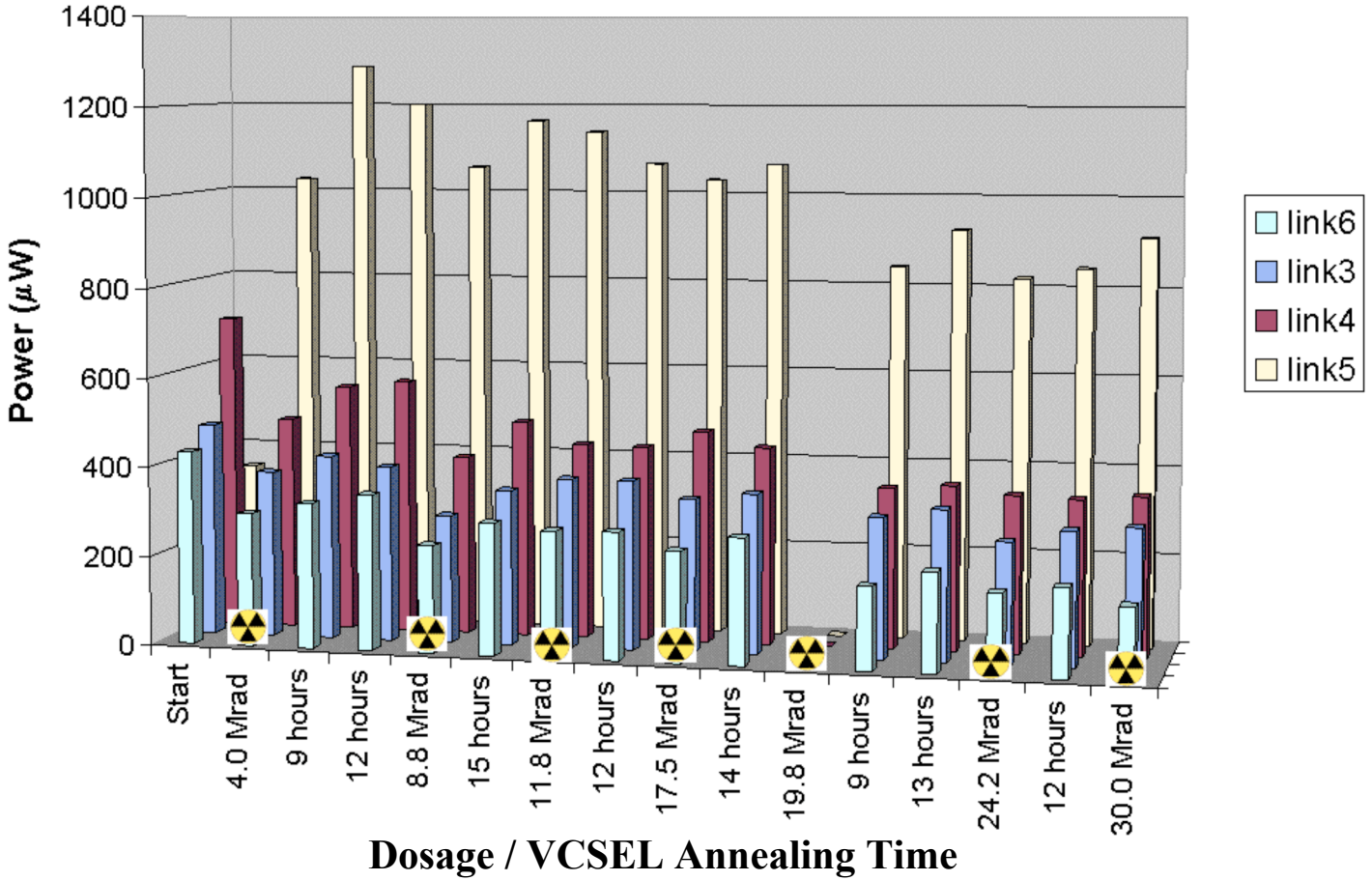


- expect bit error rate of 2.5 x 10^{-10} at PP0

Opto-power vs Dosage for April 2001 Irradiation

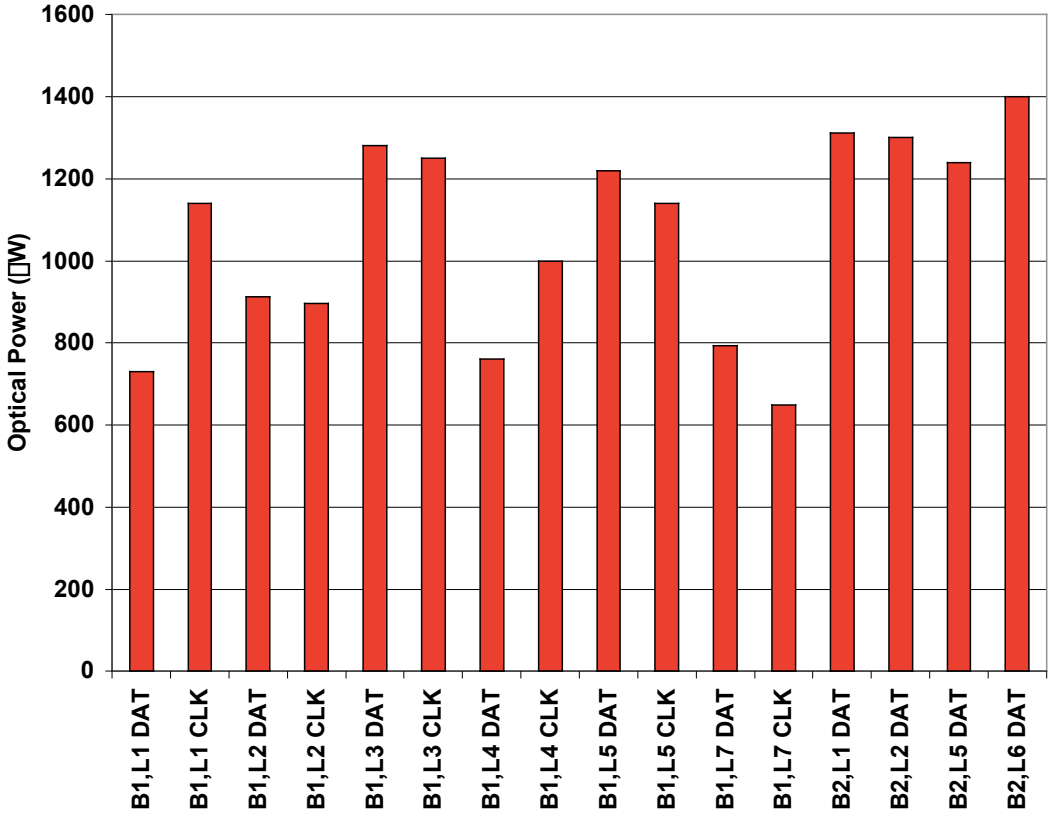


Opto-Board II: Optical Power vs. Dosage



- optical power above 300 □W after correcting for cable loss

Post-Irradiation Maximum Optical Power



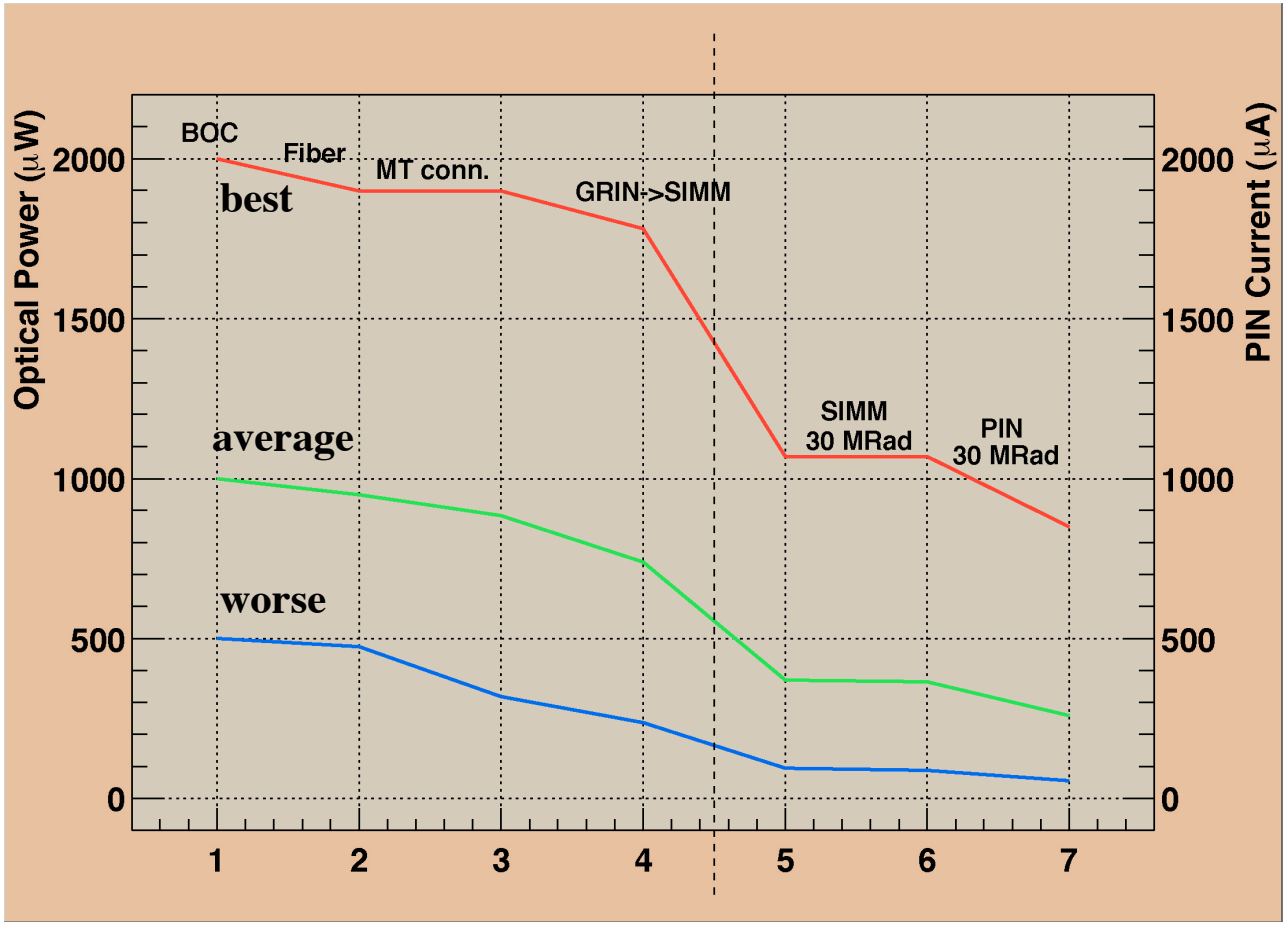
- optical power well above 300 □W after irradiation
- ⇨ radiation hardness of optical link is adequate

Irradiation Facility at OSU

- OSU research nuclear reactor can deliver
  2×10^{15} n/cm^2 (1 MeV eq.) in one day
- OSU ^{60}Co source can deliver 5 Mrad in one day

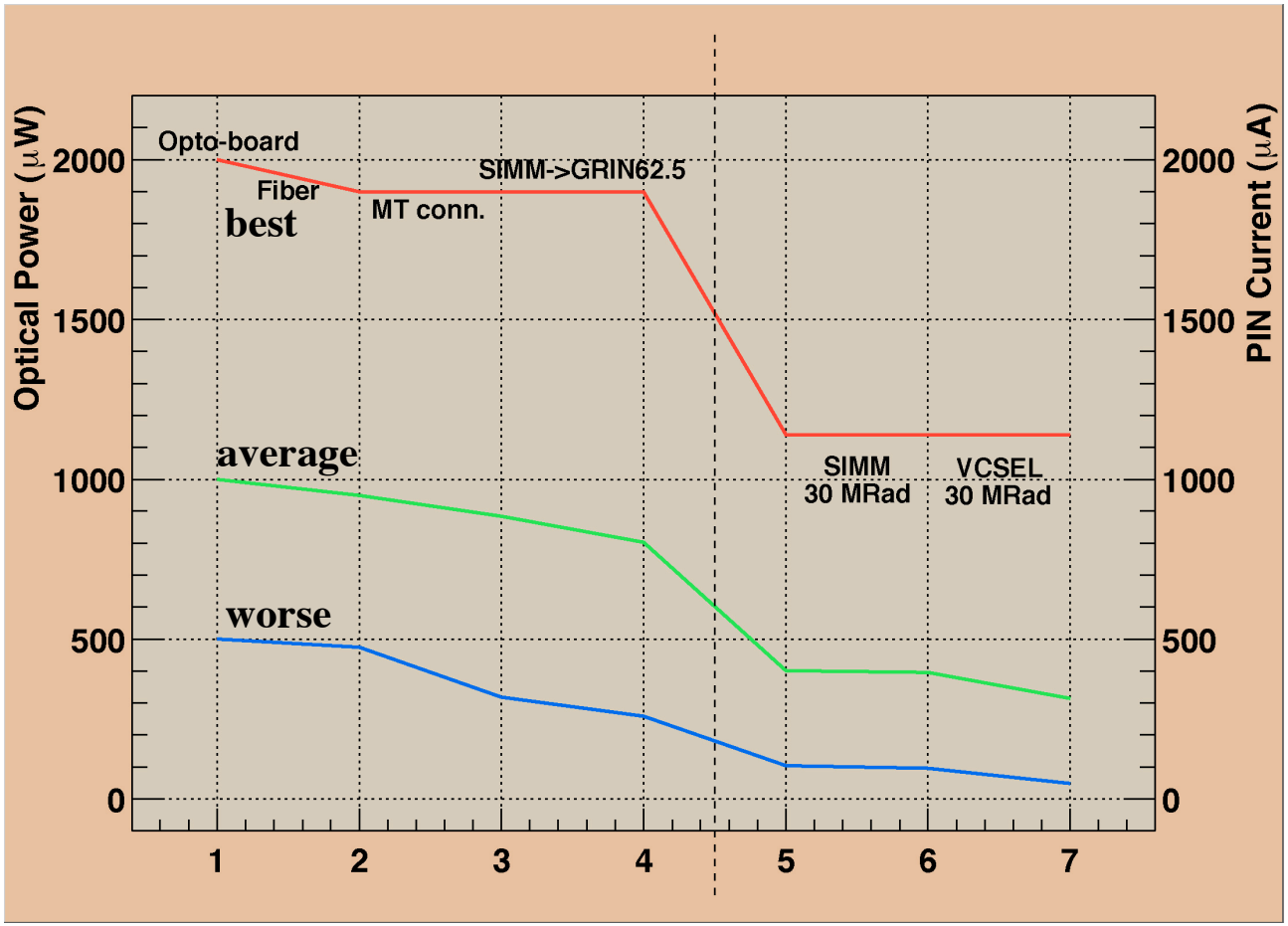
  ⇨ irradiate opto-link with neutrons and ?

TTC Link Light Budget



- PIN current at opto-board after 30 Mrad: 63-848 □A

Data Link Light Budget



- PIN current at BOC after 30 Mrad: 54-1139 μA

Status of VDC-I5

- improve rise/fall time using large number of smaller transistors

  ⇨ need to ensure 50% duty cycle at 80 MHz

✓ use larger transistor at current source to produce higher VCSEL current

- increase dim current

Status of DORIC-I5

- convert DORIC-I4 pre-amp to work with common cathode PIN
  - DORIC-I4 pre-amp:
    - high gain
    - limited dynamic range: 10-500 μA
    - sensitive to cross talk
  - DORIC-I5 pre-amp:
    - lower gain
    - larger dynamic range: 20-1000 μA
    - less sensitive to cross talk
  - ⇨ optimization in progress

Summary

- performance of VDC/DORIC-I4 is satisfactory
- VDC/DORIC-I4 is radiation hard up to at least 30 Mrad