Status of Opto-Board Development

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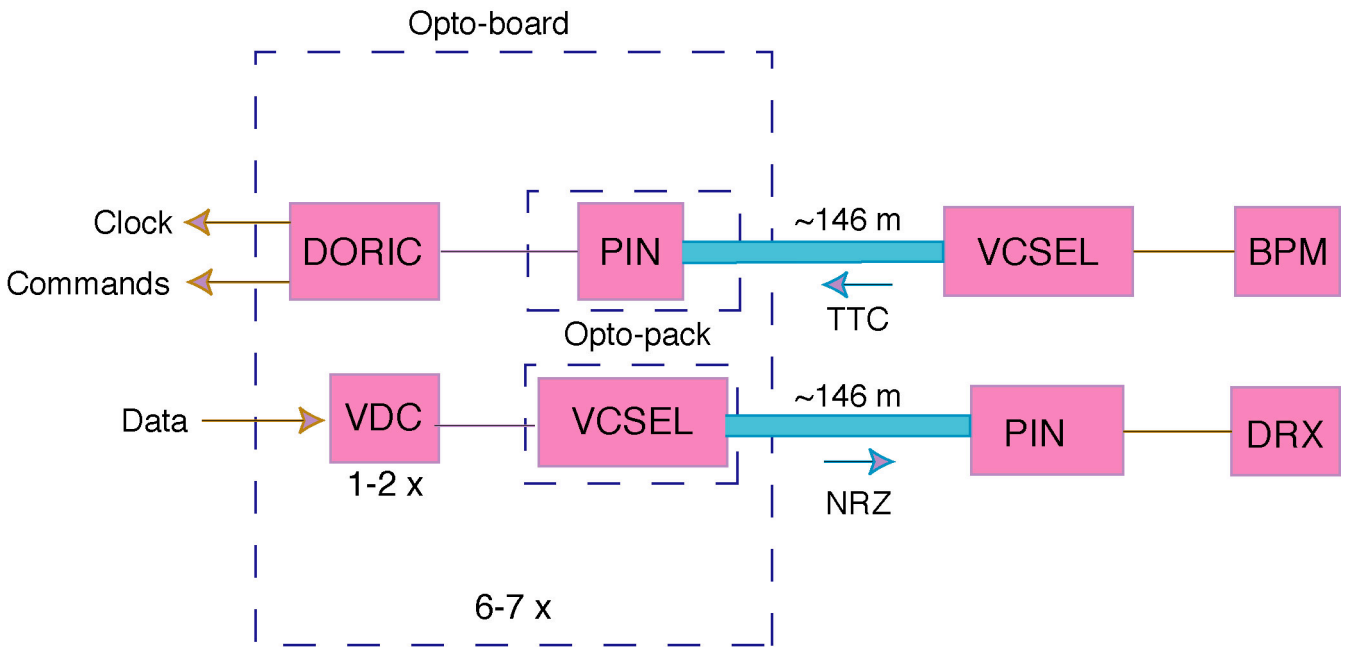
Outline

- Introduction
- Opto-Board Design
- Prototype Results
- Irradiation Results
- Conclusions

Opto-link

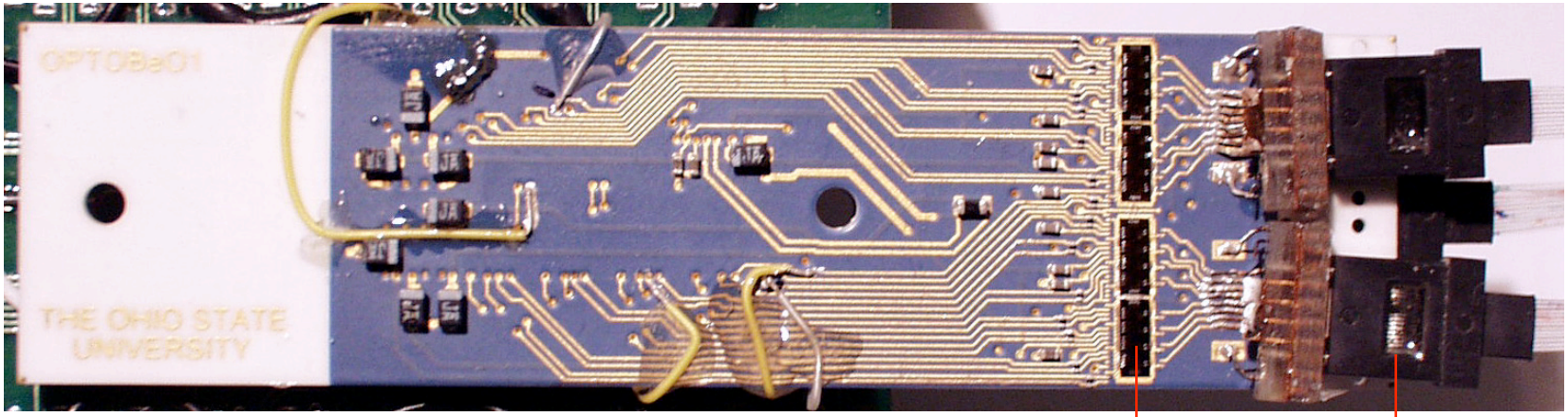

Opto-board
Clock
Commands
DORIC
PIN
~146 m
VCSEL
BPM
TTC
Opto-pack
Data
VDC
1-2 x
VCSEL
~146 m
PIN
DRX
NRZ
6-7 x

Opto-Board

- converts: optical signal ↔ electrical signal
- provide 7 optical links:
  - disks and 50% of layers 1 and 2 use 6 optical links
- two flavors:
  - disk, layers 1 and 2:
    - 2 x 4-channel DORIC + 8-channel PIN opto-pack
    - 2 x 4-channel VDC + 8-channel VCSEL opto-pack
  - B layer:
    - 2 x 4-channel DORIC + 8-channel PIN opto-pack
    - 4 x 4-channel VDC + 2 x 8-channel VCSEL opto-packs
- use BeO for heat management but prototype initially in FR4 for fast turnaround and cost saving
  - have four FR-4 prototype runs to accommodate various design changes in chips/opto-packs
- quantity needed: 212 opto-boards for two-hit system

BeO Opto-board Prototype I

- First batch:
  - 30 boards delivered in April 2003
  - several open vias on each board due to insufficient gold filling
    - ⇨ repair with wire-wrap wires
    - ⇨ working board with low PIN current thresholds for no bit errors

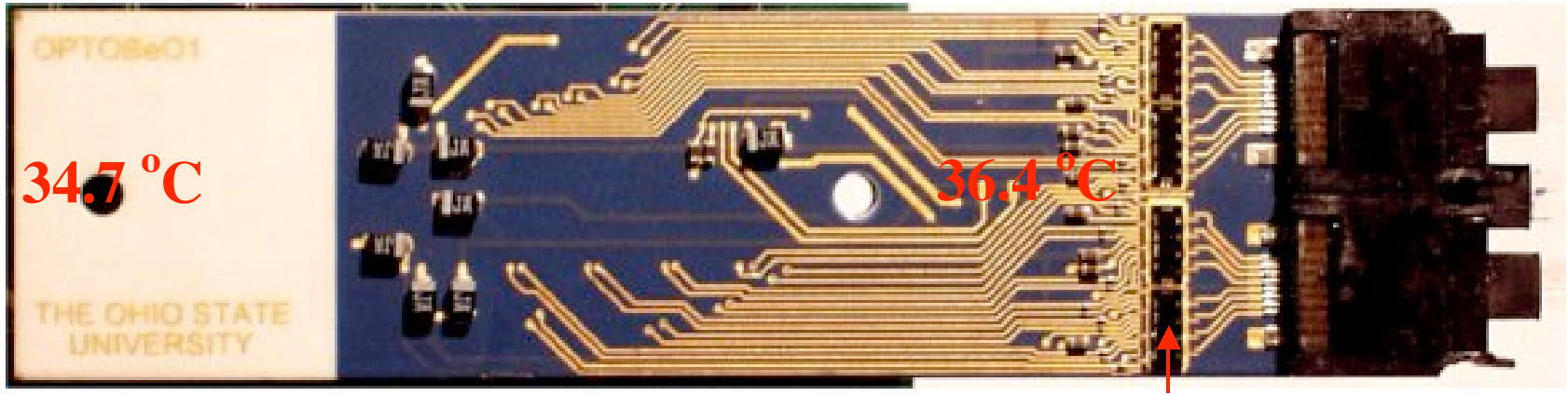


BeO Opto-board Prototype I

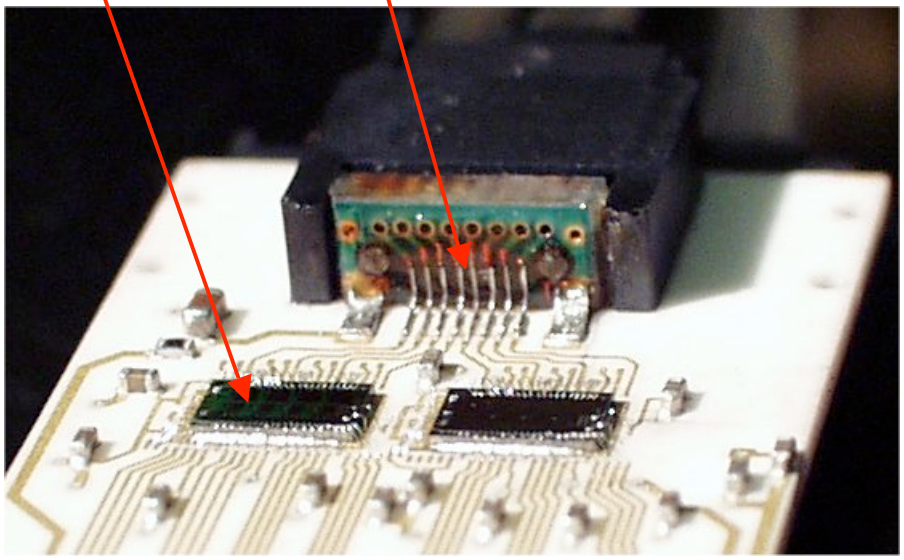
- Second batch:
  - 31 boards delivered in June 2003
  - vias overfilled and excess metal ground away
    ⇨ no open vias
  - 17 boards have shorts between power and ground lines
  - boards with no shorts have low PIN current thresholds for no bit errors

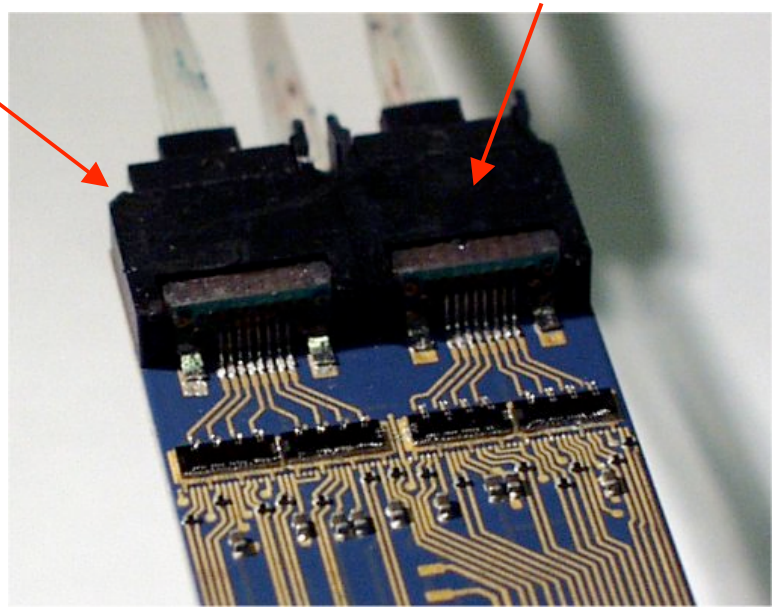
BeO Opto-board Prototype I (2nd Batch)

Ambient: 22.5 °C

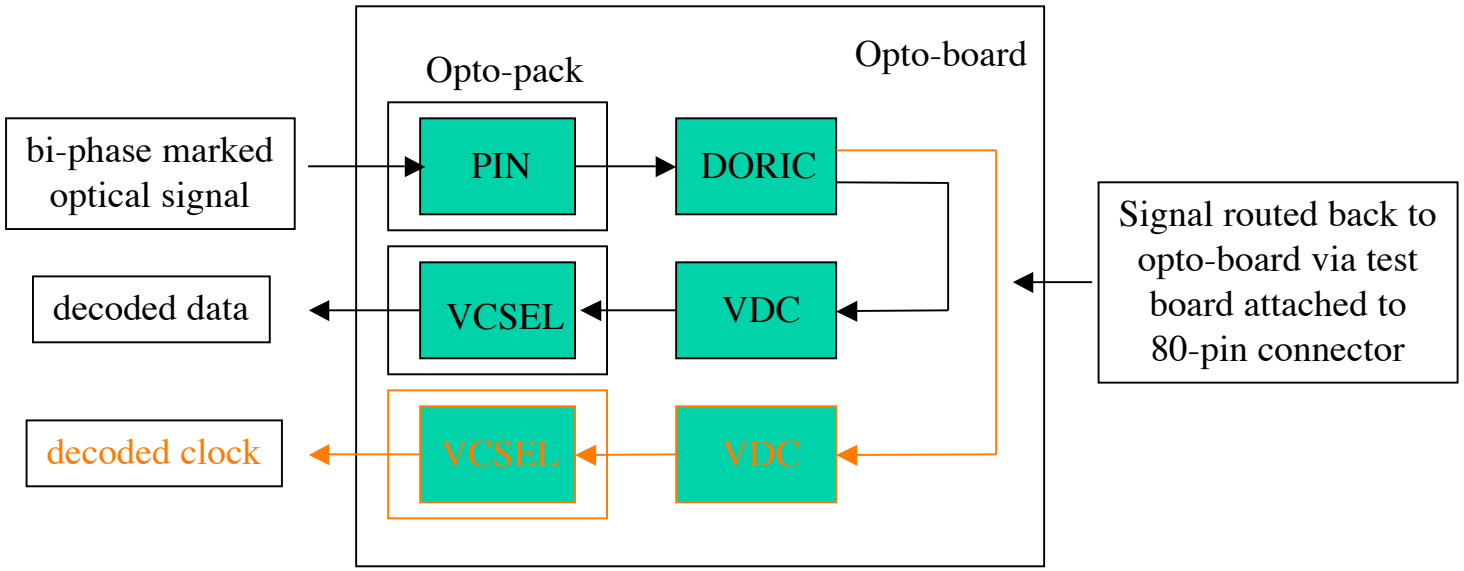


DORIC **opto-pack** **latch broken**



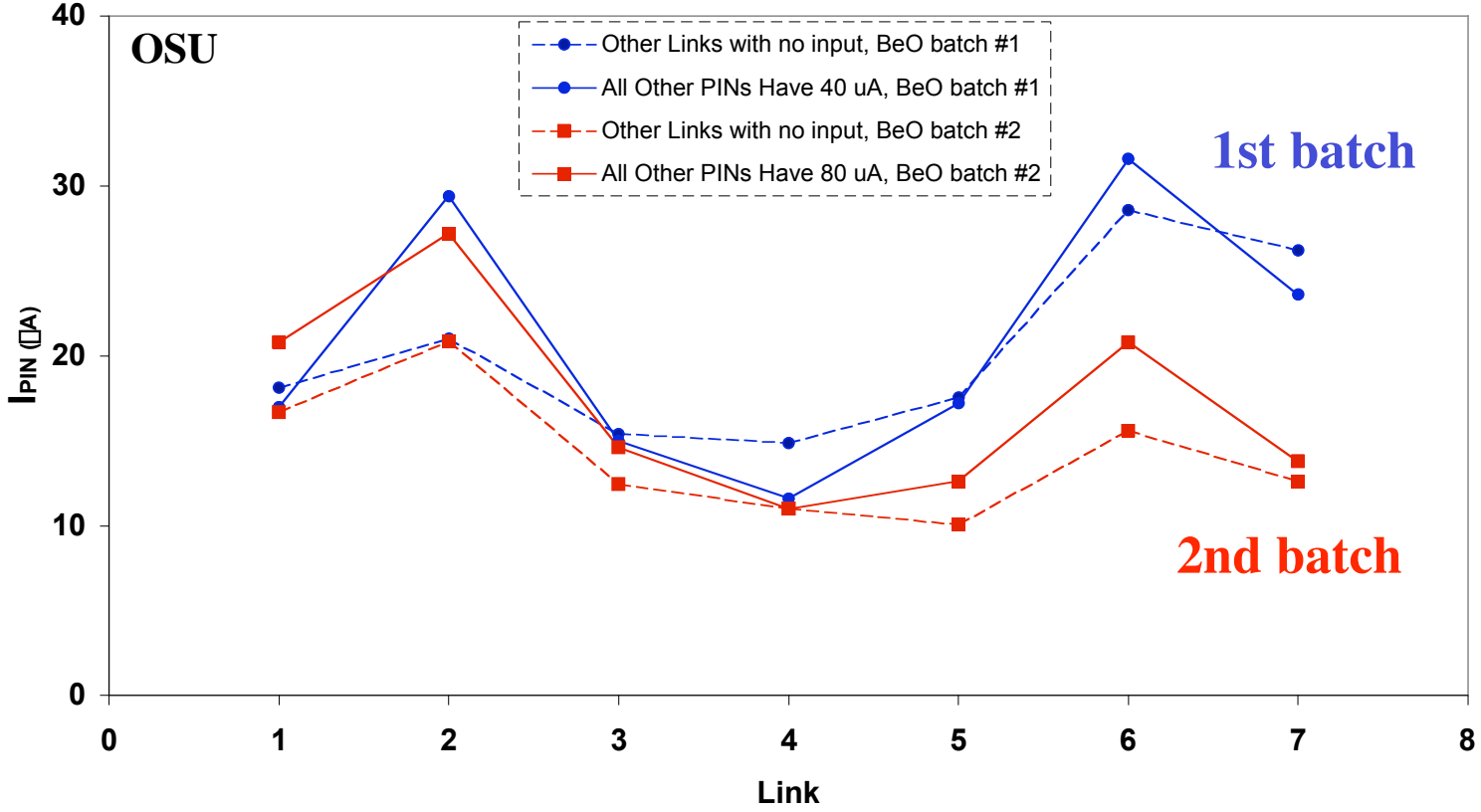


Opto-Board Testing with Loop-Back



- compare transmitted and decoded data
  - ⇨ measure minimum PIN current for no bit errors

PIN Current Thresholds for No Bit Errors



- both opto-boards have low PIN current thresholds for no bit errors independent of activity in adjacent channels

Proton Irradiations at CERN

- use 24 GeV protons at T7
- three irradiations of 0.25 □m chips since 2001:
  - cold box: purely electrical testing of chips with no optical components
  - shuttle: loop-back testing of opto-links on opto-boards
  - last irradiation is August 2003
    - 4 BeO opto-boards were tested in shuttle

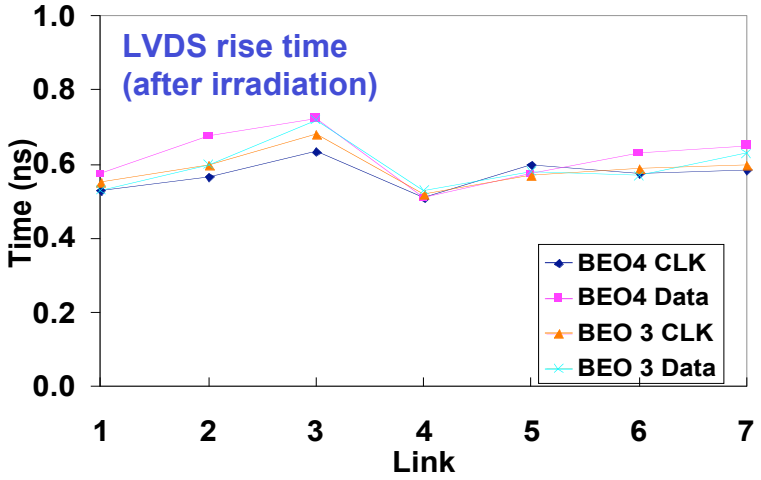
Shuttle Irradiation System

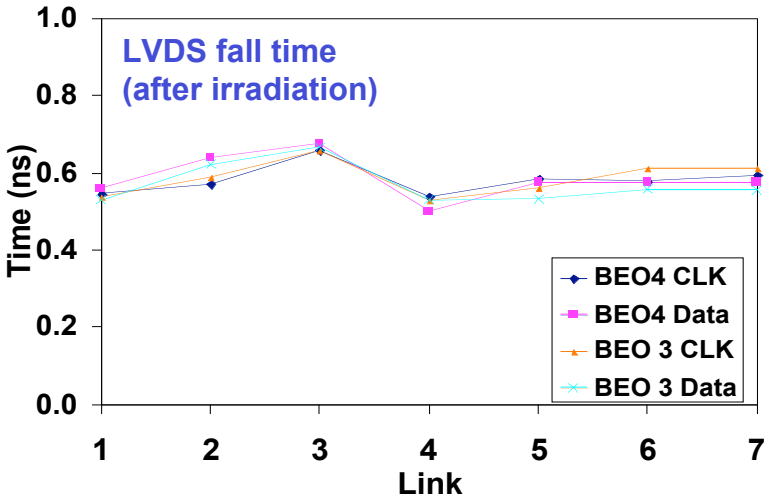
opto-board test system

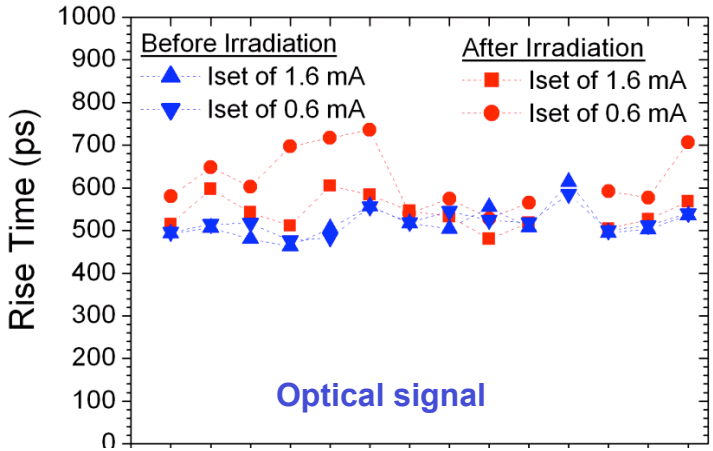
20 m fibers/wires spool

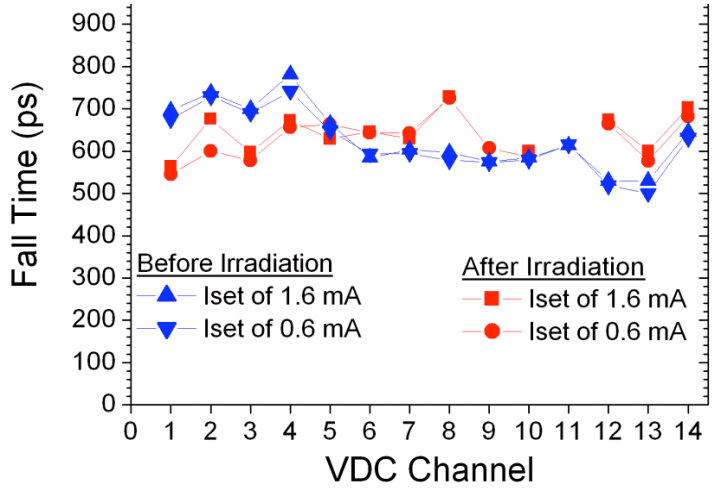
opto-boards

LVDS and Optical Rise and Fall Times



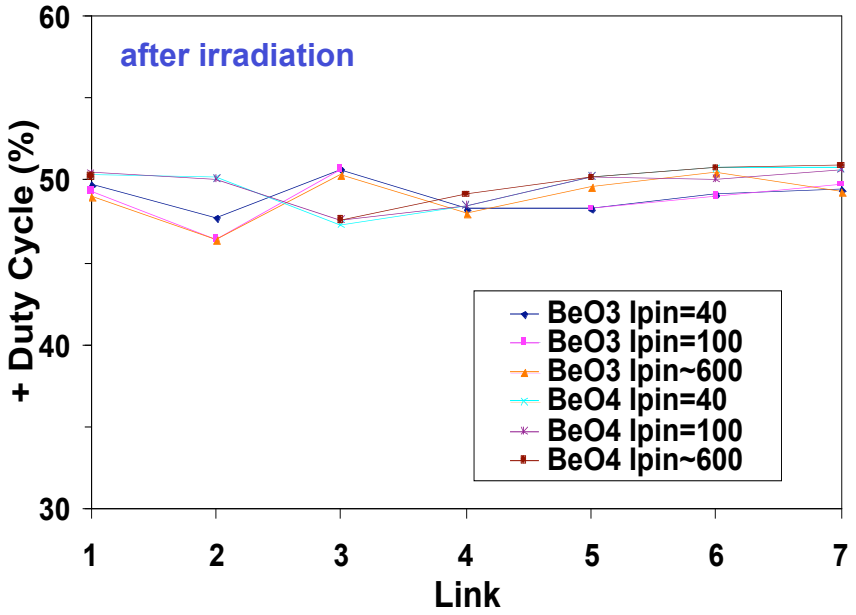


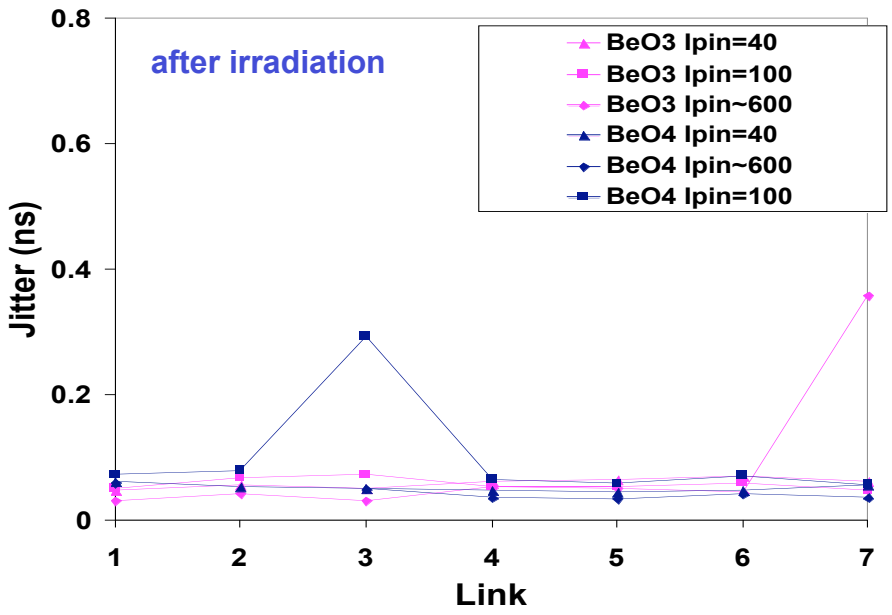




✔ rise and fall times after irradiation < 1 ns

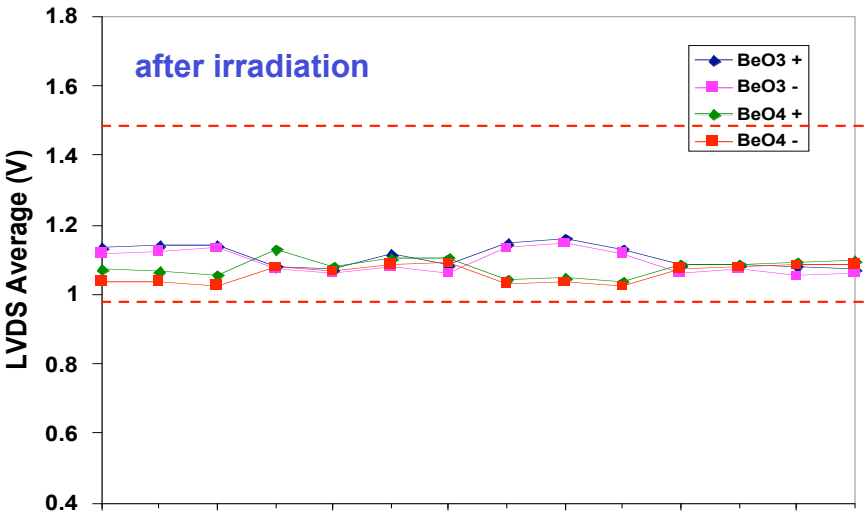
Clock Duty Cycle and Jitter

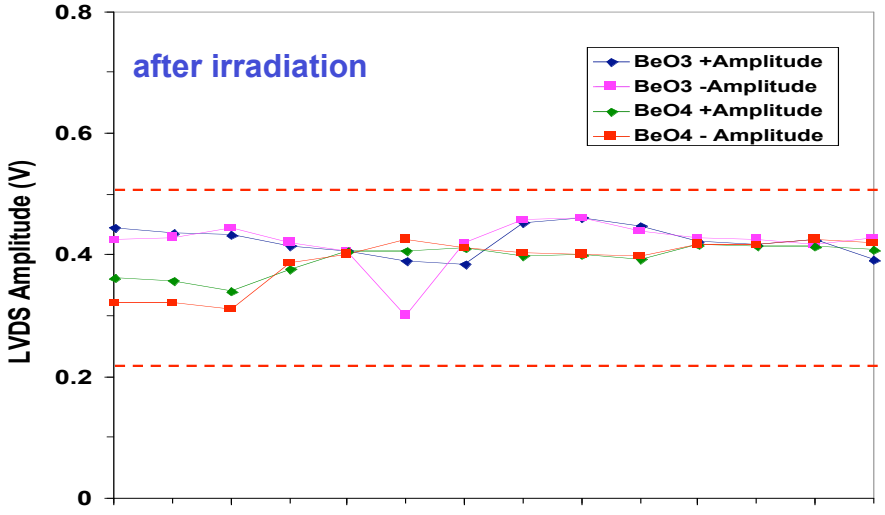




- ✔ duty cycle: (50 ± 4)%
- ✔ jitter < 1 ns

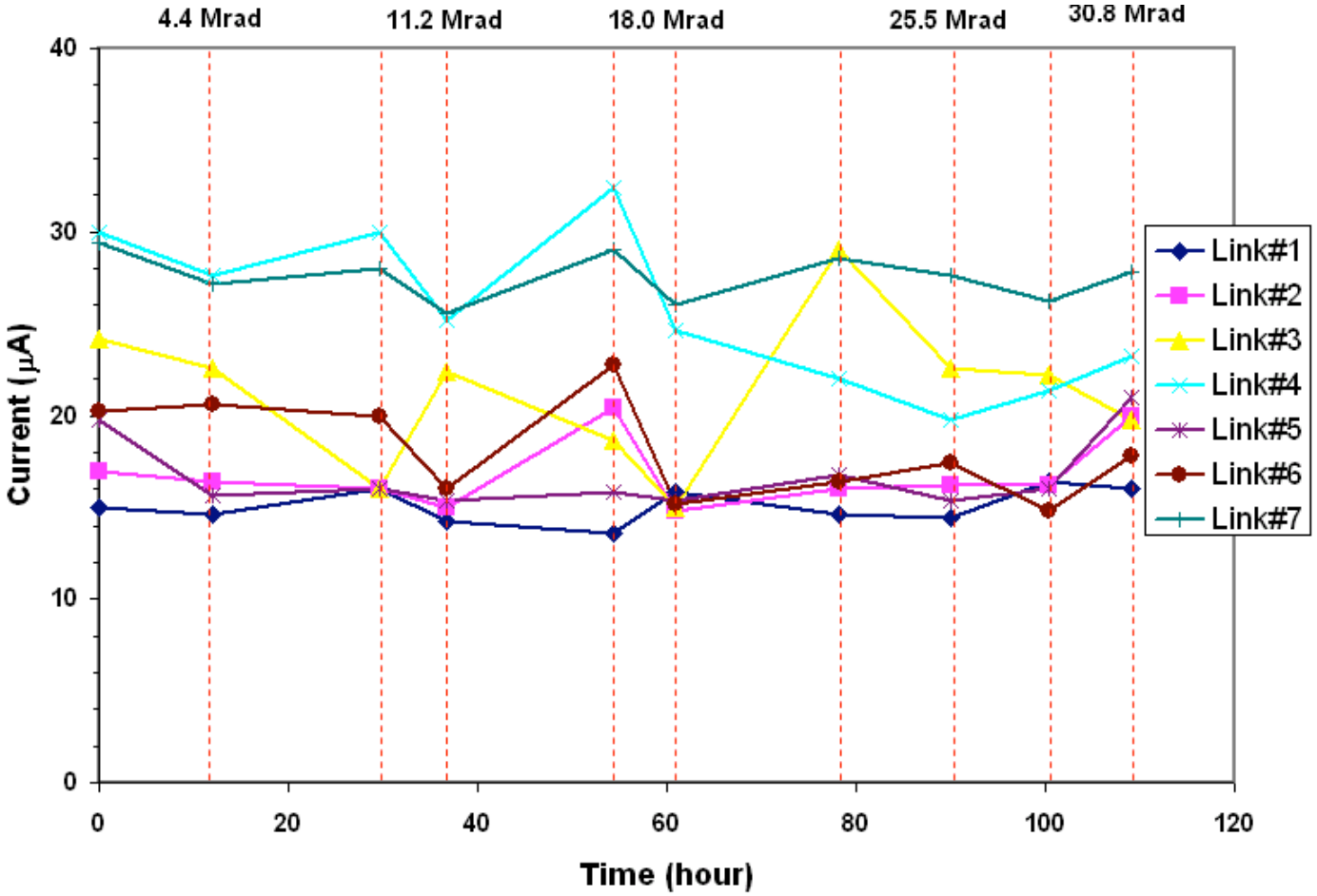
Clock LVDS Average and Amplitude





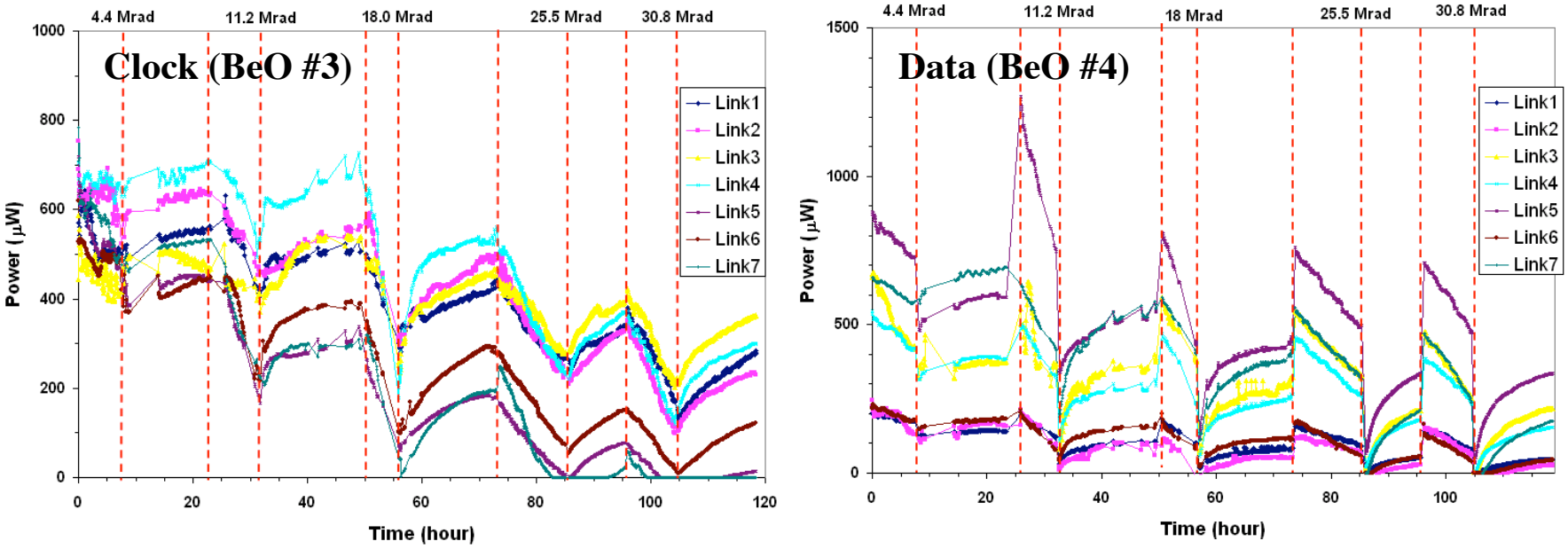
- ✔ clock LVDS average and amplitude are with spec.
- ✔ similarly for command LVDS

PIN Current Threshold vs Dosage



- PIN current thresholds for no bit errors remain constant

Optical Power vs Dosage



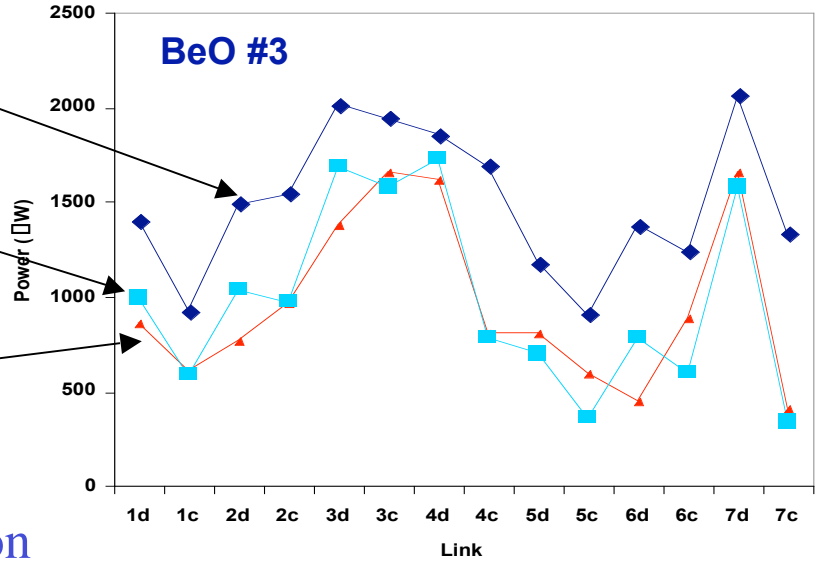
- power decreases with dosage as expected
- annealing at ~ 13 mA recovers some lost power
- some channels have low power at beginning:
  - ~35% power loss from 50 □m SIMM to GRIN
  - loss due to heating with all channels on

Optical Power with One/All Channels On

power with one channel on at I_{VCSEL} = 10 mA

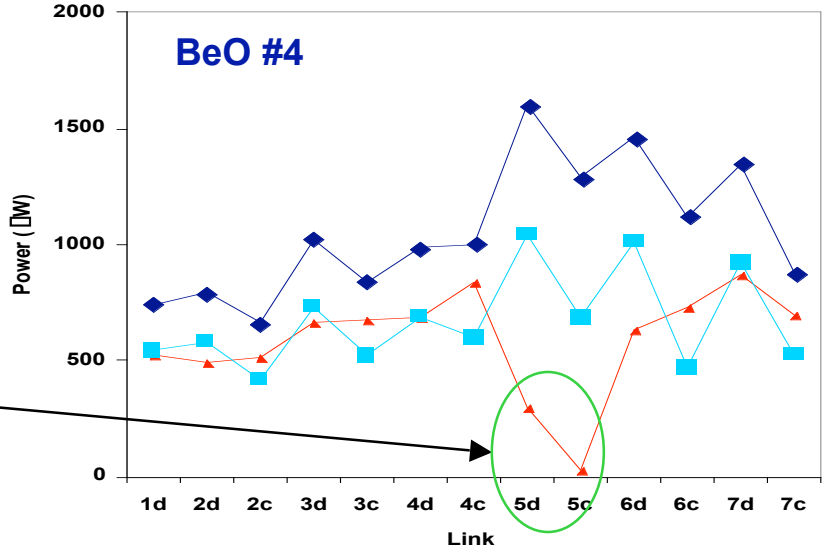
power with 10 mA per channel and all channels on

power with VDC driving VCSEL at I_{set} = 0.6 mA and all channels on



- large decreases in power with all channels on
  - same loss of power when current is driven by probe or VDC
- power of all channels after irradiation and annealing is above spec. (350 □W)

poor contact between VCSEL and VDC



Summary on BeO Opto-Board Prototype I

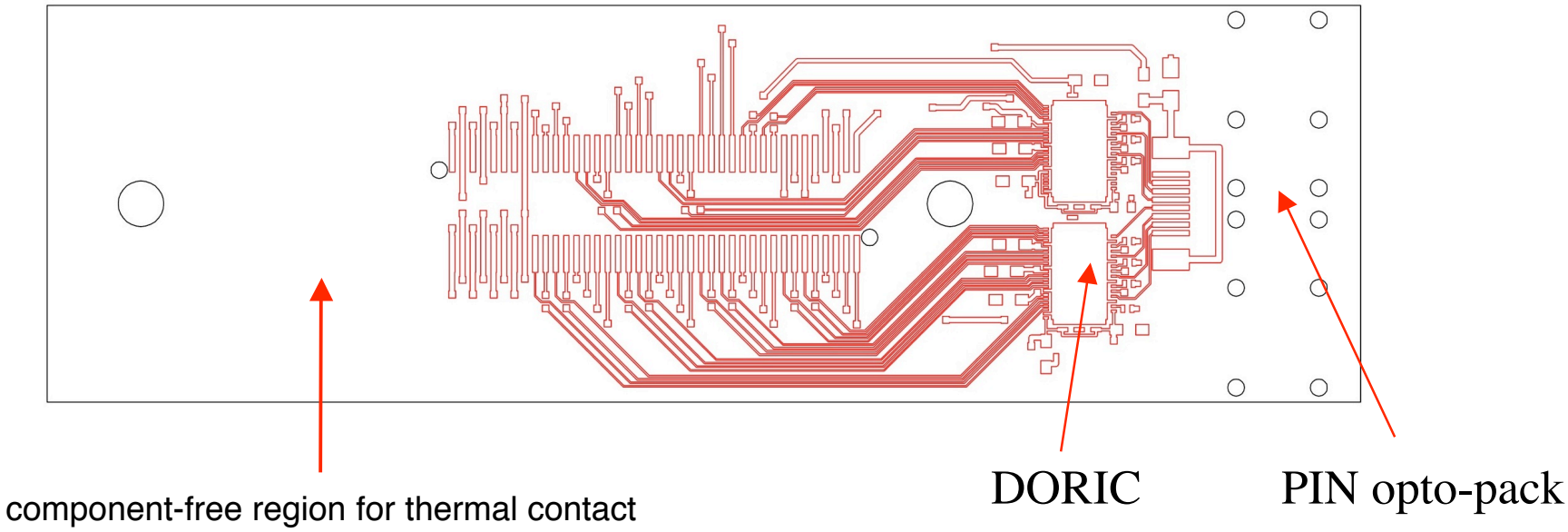
- 7 opto-boards have been populated
- all opto-boards satisfy QA even after irradiation to 30 Mrad
- 5 opto-boards have good optical power (~1 mW or above)
  - two opto-boards have lower power
    but still above spec. after irradiation

⇨ demonstrate that we can fabricate opto-boards of high quality

BeO Opto-Board Prototype II

- fabricate two opto-board flavors instead of one in prototype I
  - layers 1, 2 and disk:
    - each pixel module uses one link for transmitting data
      - ⇨ VCSEL opto-pack serves 7 links (7 modules)
  - B layer:
    - each pixel module uses two links in same fiber ribbon for transmitting data
      - ⇨ VCSEL opto-pack #1 serves 8 links (4 modules)
      - ⇨ VCSEL opto-pack #2 serves 6 links (3 modules)
- use more experienced/expensive vendor
  - fabricated several types of BeO boards for CDF

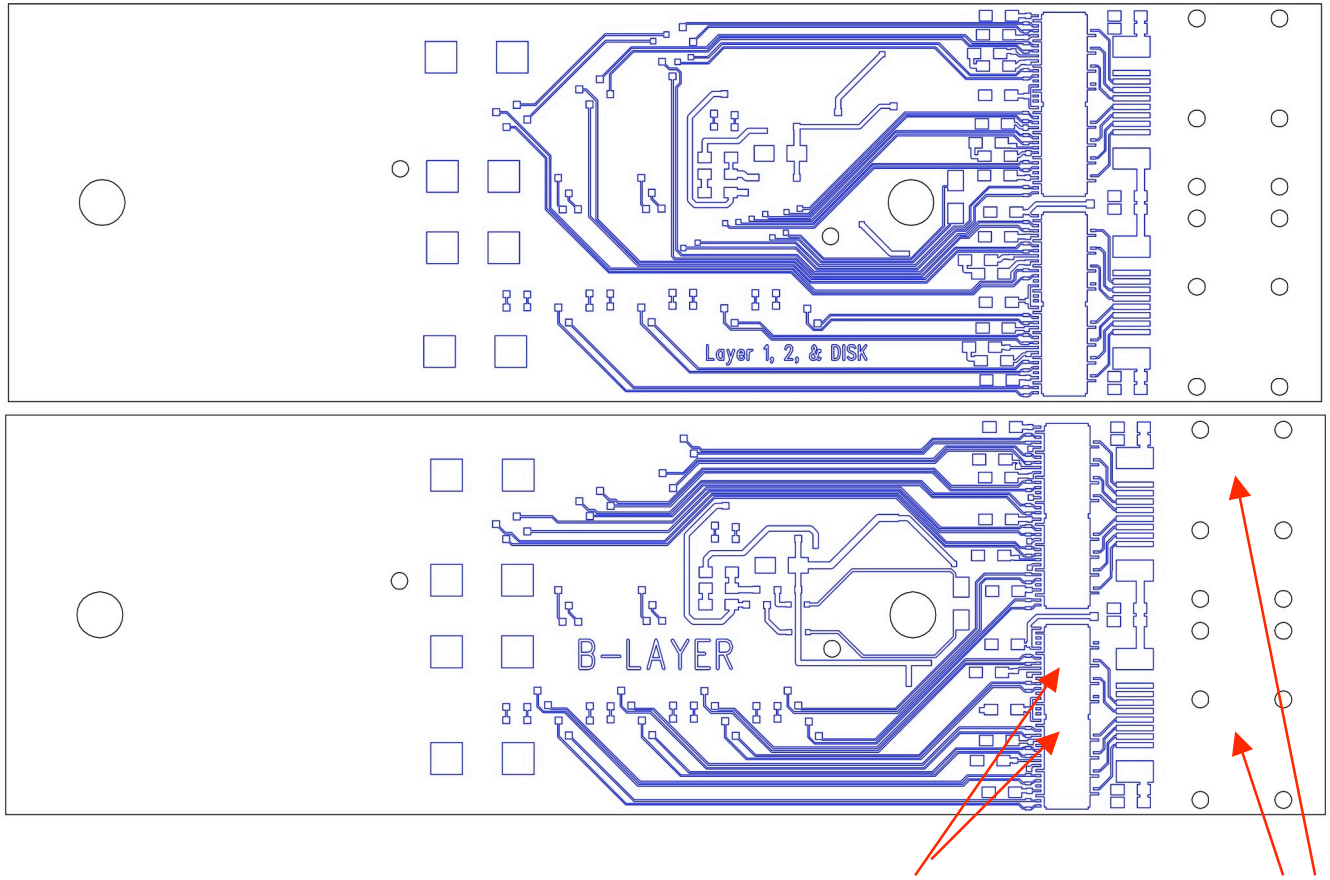
BeO Opto-Board Prototype II (Bottom)



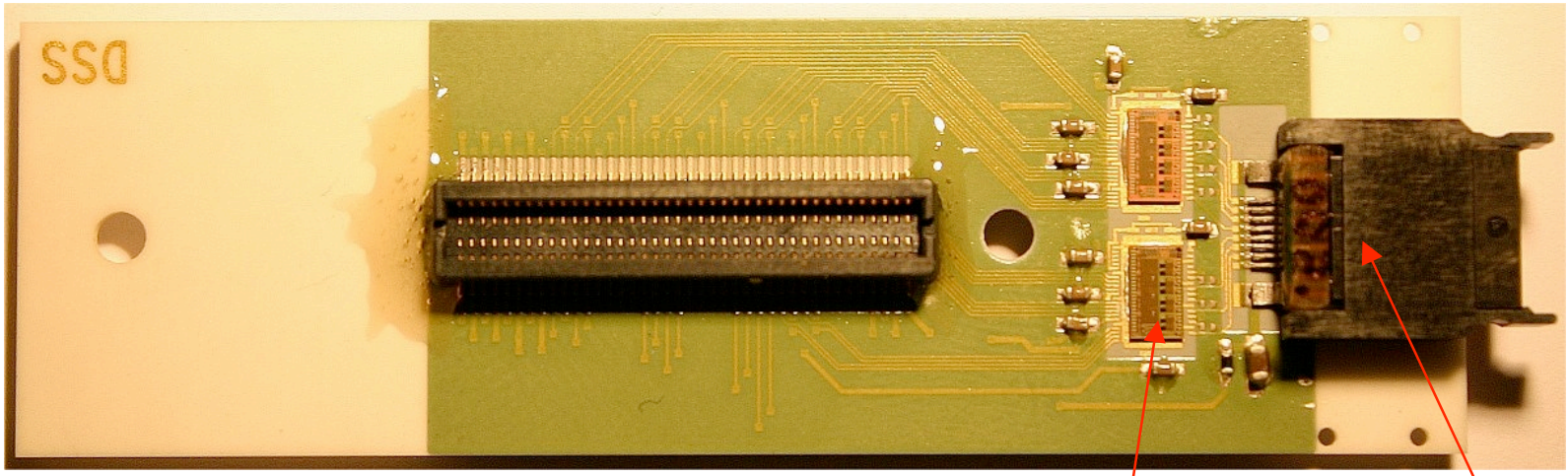
BeO Opto-Board Prototype II (Top)

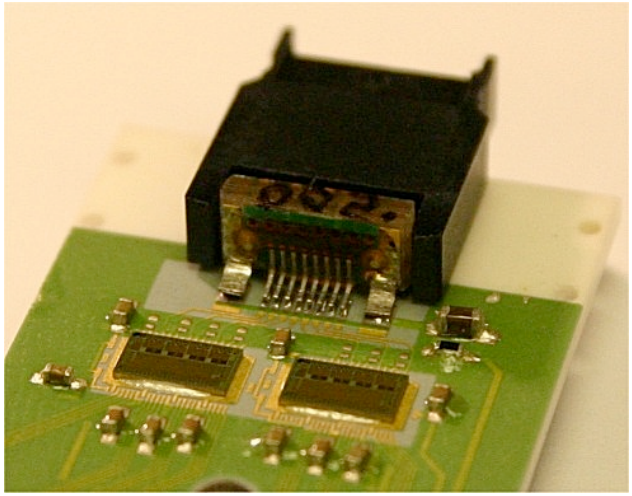
Disk and layers 1 & 2

B layer

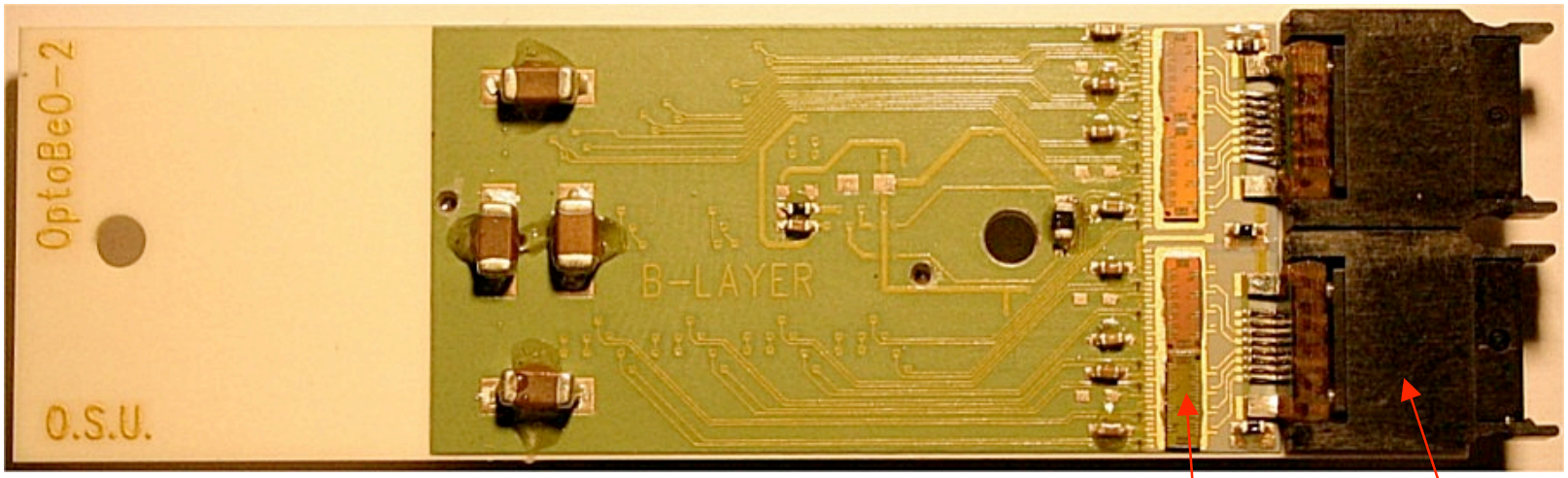


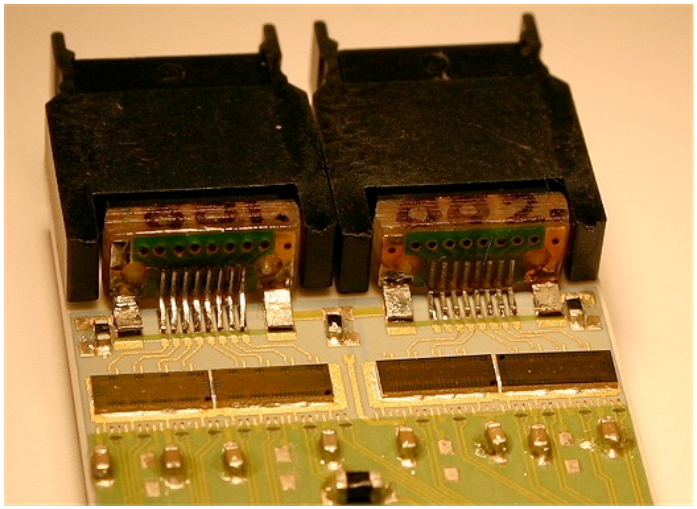
BeO Opto-Board Prototype II (Top)





BeO Opto-Board Prototype II (Bottom)





VCSEL opto-pack

VDC

Production Plan

- 13/2/04: delivery of 14 opto-boards of each flavor
  - populate one board of each flavor to verify design
- 27/2/04: ship 10 boards of each flavor to Advanced Assembly Inc for passive components mounting
- 5/3/04: delivery of boards by Advanced Assembly Inc
- 5/4/04: complete production of prototype opto-boards
  - start production of 300 opto-boards at CPT
- 5/6/04: delivery of production opto-boards by CPT
- 5/7/04: delivery of opto-boards with passive components
- 5/11/04: complete production of opto-boards (2 opto-boards/day)

Production Procedure

- mounting of passive components by Advanced Assembly Inc
- mechanical tolerance test
- electrical short test
- mounting of DORIC/VDC
- mounting of opto-packs/housings
- wire bonding
- basic functionality test
- encapsulation
- burn-in @ 50^{o}C for 3 days/10 thermal cycles between @-25 & 50^{o}C
- basic functionality test @-25 & 50^{o}C and QA @ 10^{o}C

Production Site/Experience/Personnel

- site: OSU and Siegen
- experience:
  - OSU: fabricated FR4 opto-boards + 5 BeO opto-boards
    - populated 150 BeO boards with 0.5 million wire bonds for CLEO III
    - use automatic wire bonder in-house
  - Siegen: fabricated FR4 opto-boards + 2 BeO opto-boards
    - use automatic wire bonder at Bonn
- personnel:
  - OSU: 1 physicist (+ 1 vacancy) + 2 technicians + 2 p.t. technicians + 2 undergraduate workers
  - Siegen: 2 physicists + 1 graduate student + 1 technician + 2 undergraduate workers
- OSU will perform mechanical/short for Siegen

Summary

- has fabricated seven BeO opto-boards from prototype I
  - opto-boards pass QA even after irradiation up to ~30 Mrad
- BeO opto-boards from prototype II have been received
  - ready for production if no design error is found