Radiation-Hard Optical Link for SLHC

W. Fernando, K.K. Gan, A. Law, H.P. Kagan, R.D. Kass, S. Smith
The Ohio State University

M.R.M. Lebbai, P.L. Skubic
University of Oklahoma

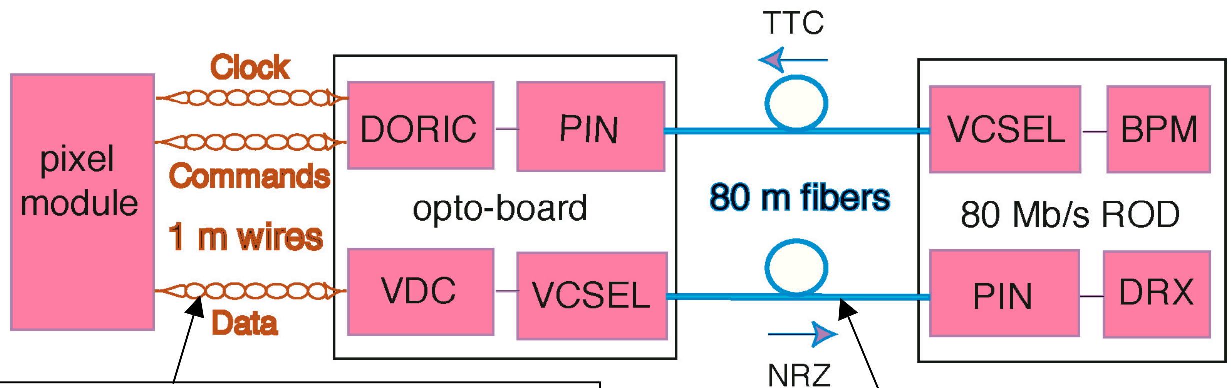
July 20, 2007

Outline

- Introduction
- Bandwidth of micro twisted-pair cables
- Bandwidth of fusion spliced SIMM-GRIN fiber
- Radiation hardness of PIN/VCSEL arrays
- Results on MT-style optical packages based on BeO
- Summary

ATLAS Pixel Opto-Link Architecture

- ATLAS is a detector studying pp collisions of 14 TeV at CERN
  - pixel detector is innermost tracker
  - detector upgrade planned for Super-LHC in 2015



micro twisted pairs decouple pixel and opto module
⇨ simplify both design/production

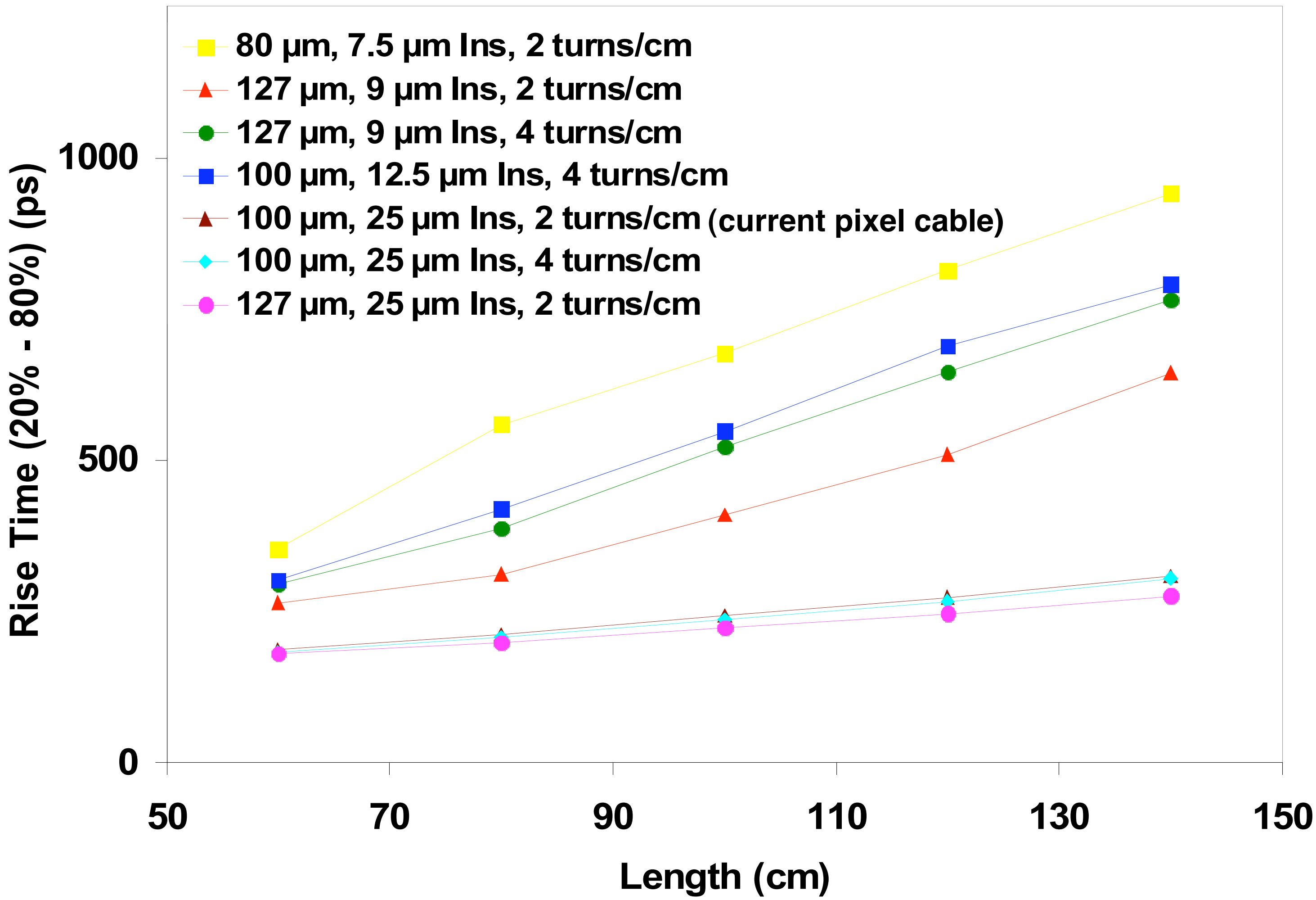
8 m of rad-hard/low-bandwidth SIMM fiber fusion spliced to 70 m rad-tolerant/medium-bandwidth GRIN fiber

⇨ upgrade based on current pixel link architecture to take advantage of R&D effort and production experience?

R&D Issues for SLHC

- bandwidth of ~ 1 Gb/s is needed
  - can micro twisted pair transmit at this speed?
  - can fusion spliced SIMM/GRIN fiber transmit at this speed?
- can PIN/VCSEL arrays survive SLHC radiation dosage?

Bandwidth of Micro Twisted Pairs



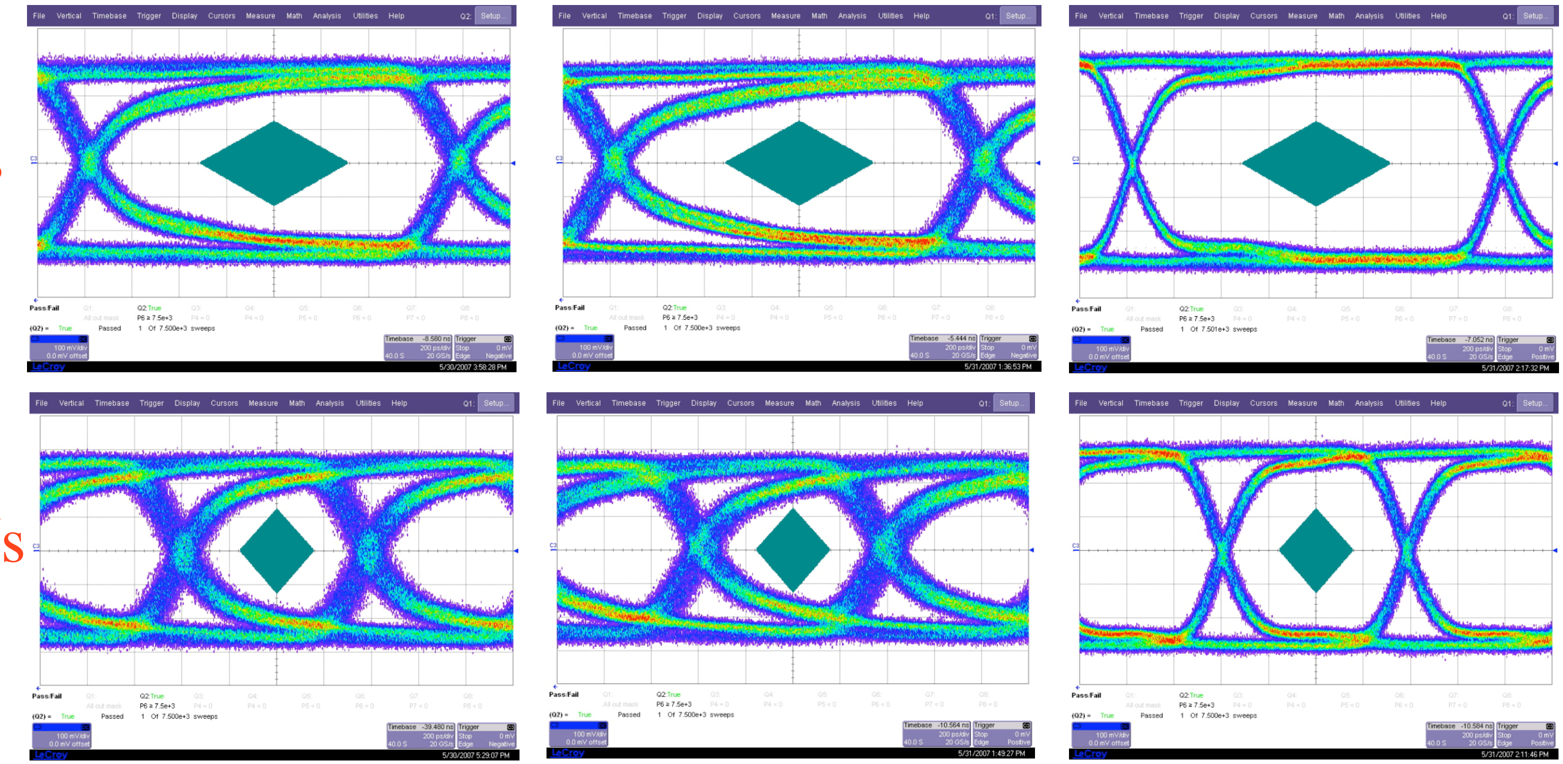
- current pixel cable with thick insulation is quite optimum!

Eye Diagrams

127 μm cable 140 cm | 100 μm current pixel cable 140 cm | 60 cm

640 Mb/s

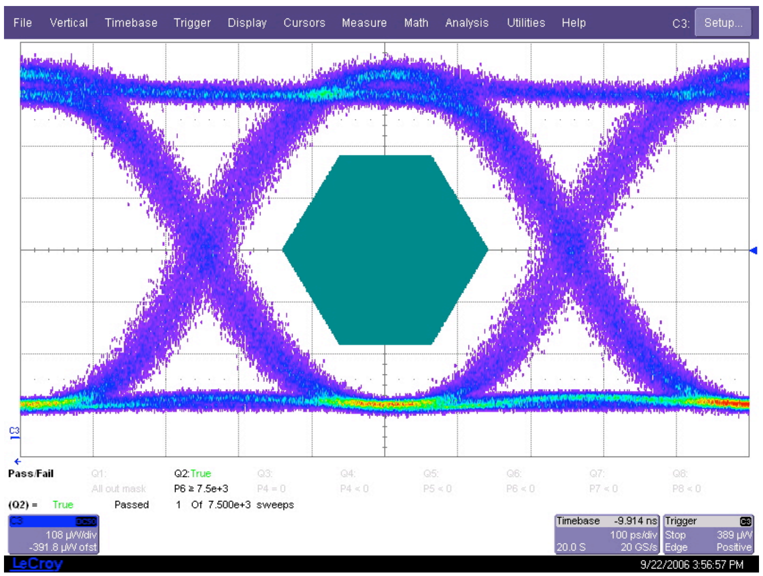
1280 Mb/s



- transmission at 640 Mb/s is adequate
- transmission at 1280 Mb/s may be acceptable
- 127 μm cable is slightly better

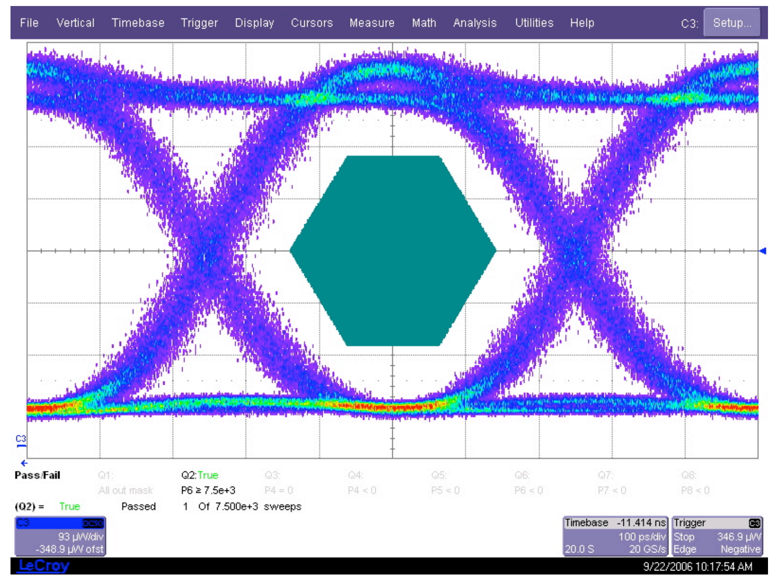
Bandwidth of Fusion Spliced Fiber

1 m GRIN fiber



2 Gb/s

8 + 80 m spliced SIMM/GRIN fiber



- transmission up to 2 Gb/s looks adequate

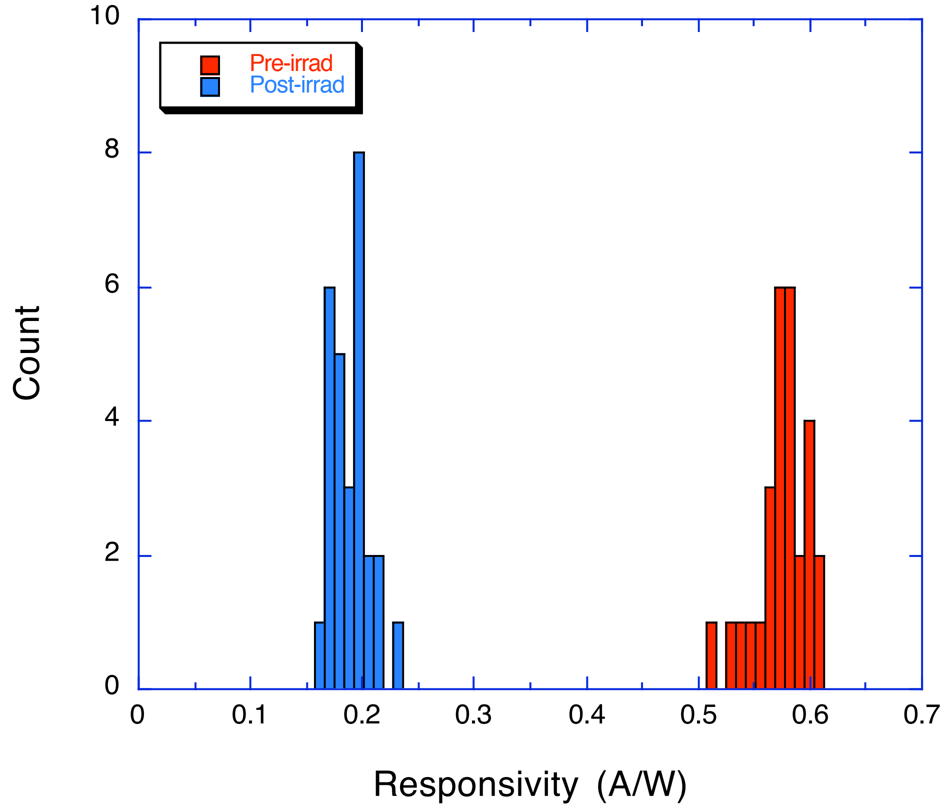
Radiation Level at SLHC

- Optical link of current pixel detector is mounted on patch panel:
  - ⇨ much reduced radiation level:
    - Si (PIN) @ SLHC:
      - 2.5×10^{15} 1-MeV n_{eq}/cm^2
      - 4.3×10^{15} p/cm^2 or 114 Mrad for 24 GeV protons
    - GaAs (VCSEL) @ SLHC:
      - 14×10^{15} 1-MeV n_{eq}/cm^2
      - 2.7×10^{15} p/cm^2 or 71 Mrad for 24 GeV protons
    - above estimates include 50% safety margin

Requirements for PIN/VCSEL

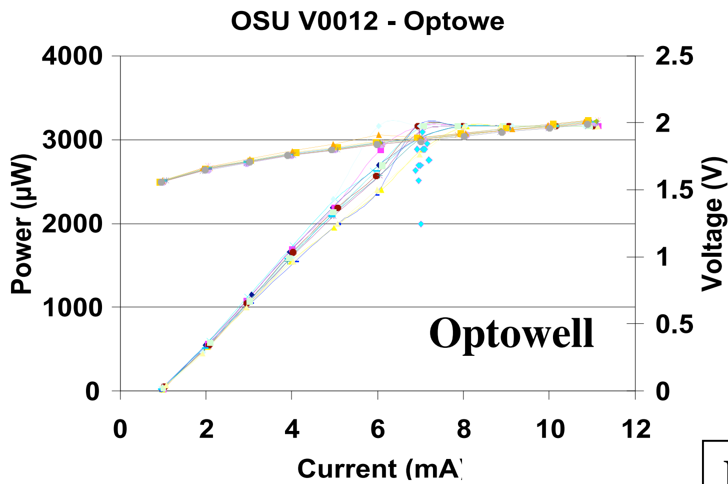
- PIN:
  - What is responsivity after irradiation?
  - What is rise/fall time after irradiation?
- VCSEL:
  - driver chip most likely be fabricated with 0.13 μm process
    - nominal operating voltage is 1.2 V
    - thick oxide option can operate at 2.5 V
    - ⇨ VCSELs must need < 2.3 V to produce 10 mA or more
  - What is rise/fall time after irradiation?
  - What is optical power after irradiation?
  - What current is needed for annealing?

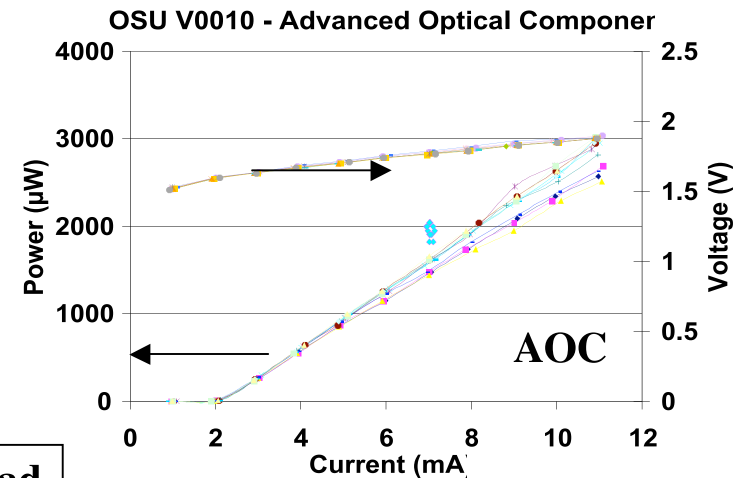
PIN Responsivity



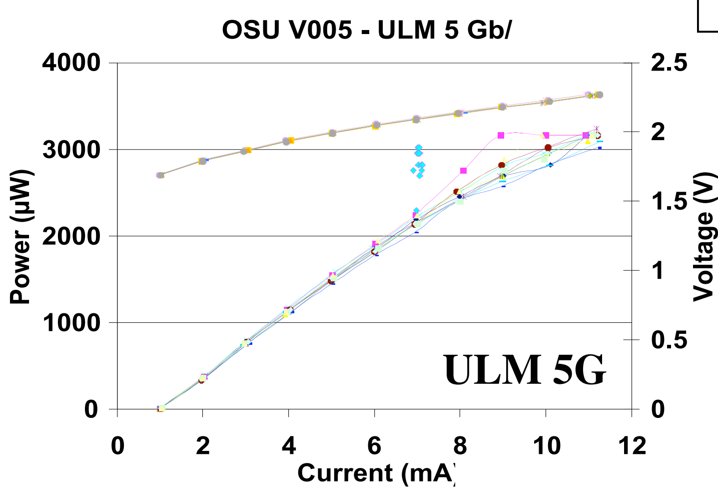
- responsivity decreases by 65% after SLHC dosage

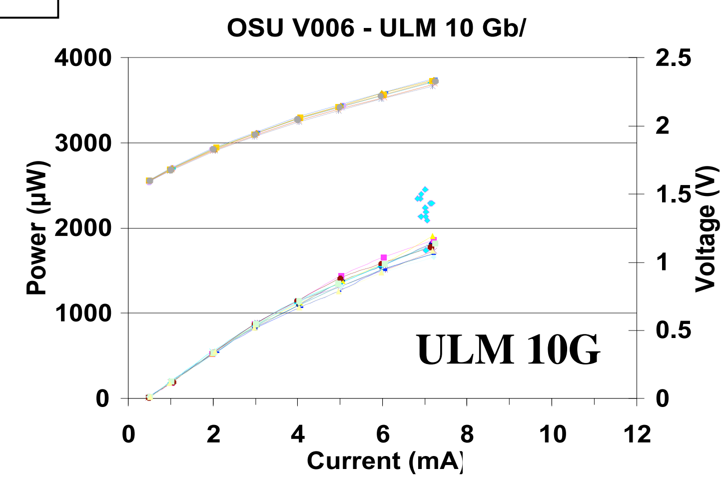
VCSEL LIV Characteristics





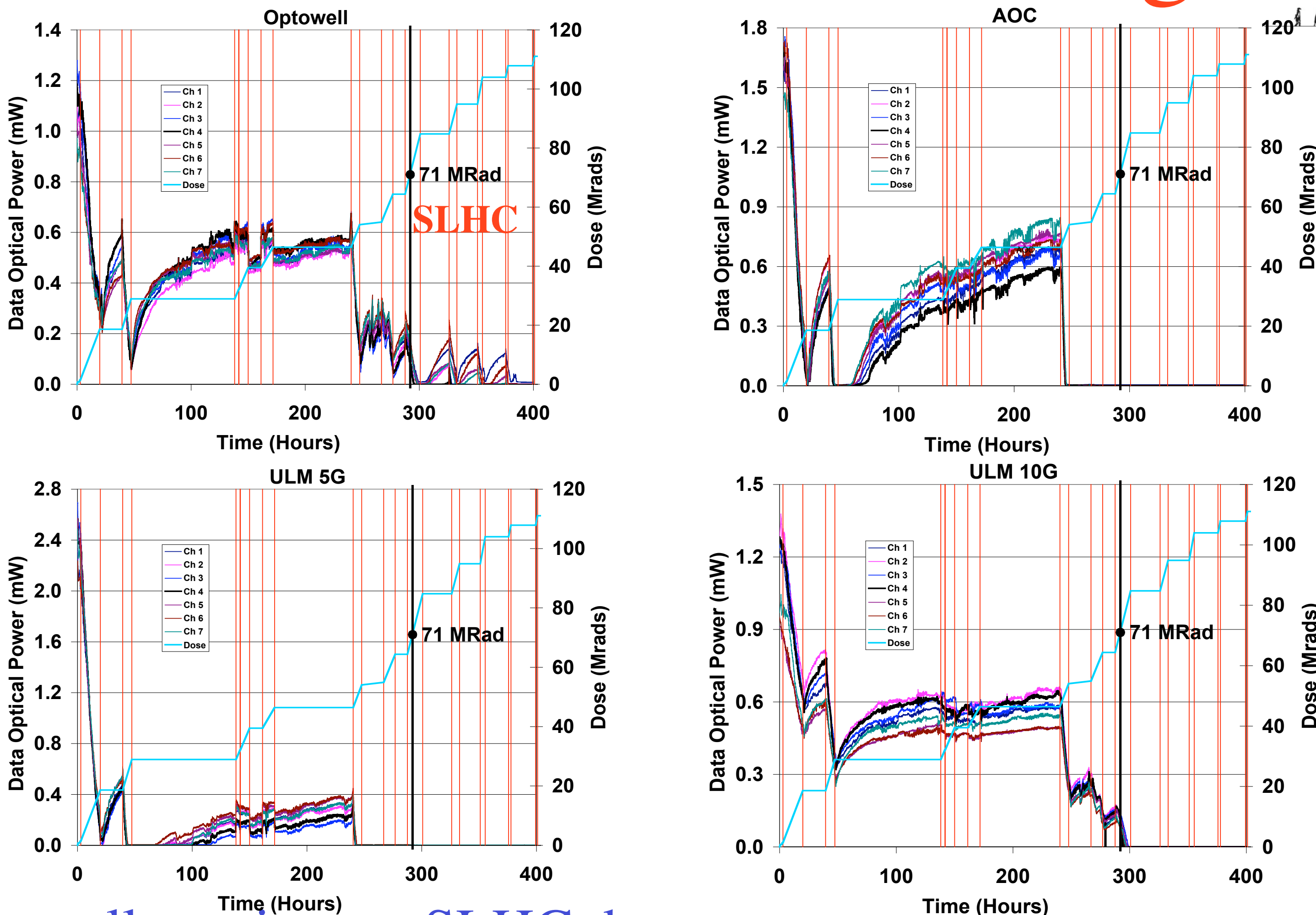
Pre-irrad





- ULM requires higher voltage to operate
- all arrays have very good optical power

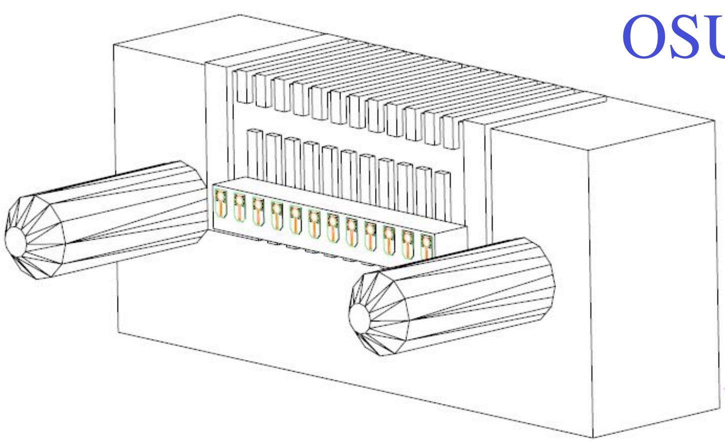
VCSEL Power vs Dosage



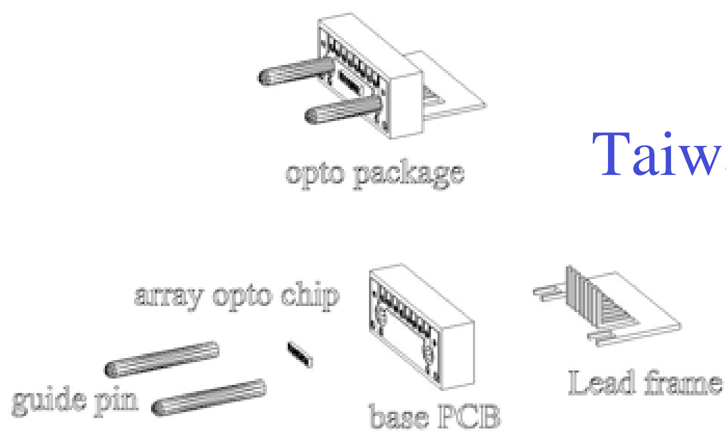
- Optowell survives to SLHC dosage
- more VCSELs might survive with more annealing during irradiation

Opto-Pack Development

- current pixel detector uses Taiwan optical packages
  - ☹ VCSEL mounted on PCB with poor heat conduction
  - ☹ micro soldering of 250 μm leads is difficult
- Ohio State develops new opto-pack for SLHC
  - uses BeO base with 3D traces for efficient heat removal
  - wire bond to driver/receiver chip



OSU

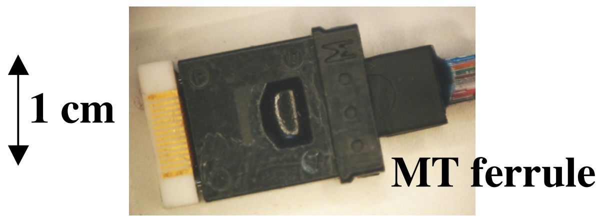


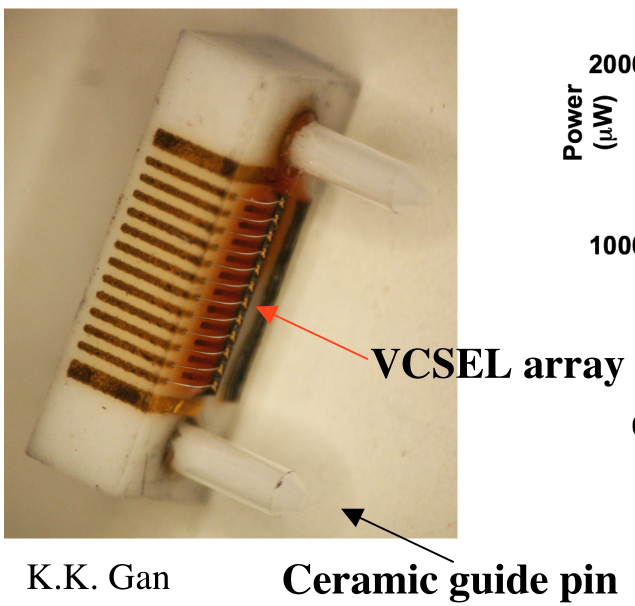
Taiwan

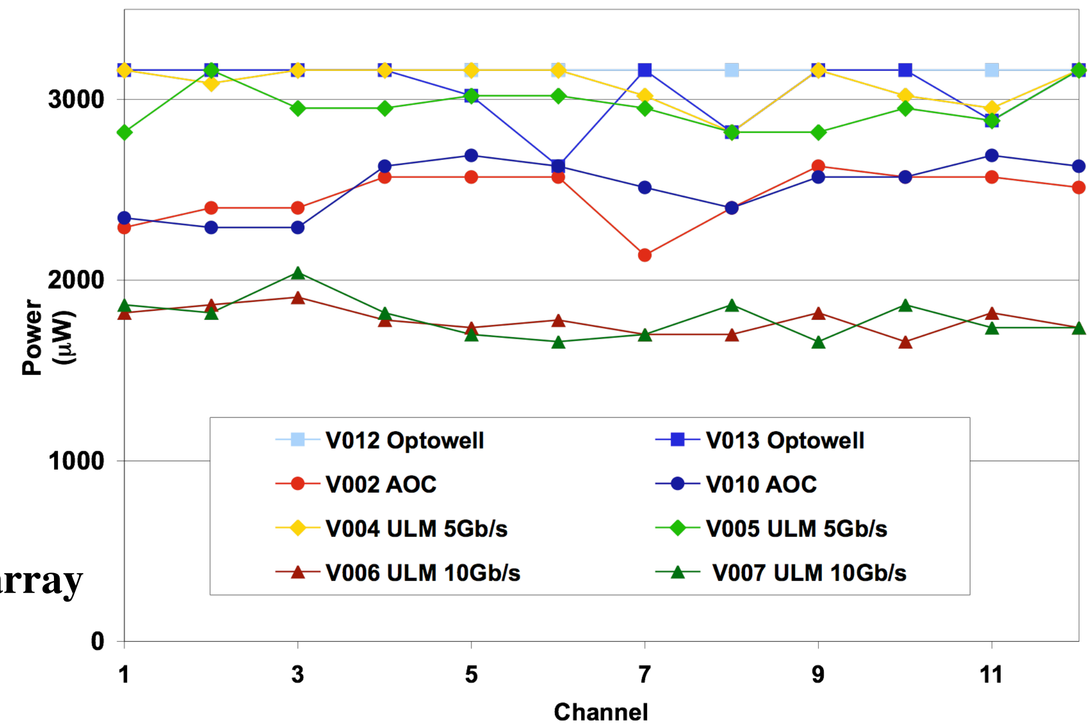
Results on Opto-Packs

- 30 VCSEL/PIN opto-packs have been fabricated
  - all VCSEL opto-packs have good coupled power

⇨ principle of new opto-pack has been demonstrated







Summary

- micro twisted-pair cable of current ATLAS pixel detector can be used for transmission up to 1 Gb/s
- fusion spliced SIMM/GRIN fiber can transmit up to 2 Gb/s
- PIN responsivity decreases by 65% after SLHC dosage
- Optowell VCSEL survives SLHC dosage

⇨ current opto-link architecture satisfies SLHC requirements

- compact MT-style opto-pack based on BeO has been developed