Radiation-Hard/High-Speed Data Transmission using Optical Links

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Outline

- Introduction
- Bandwidth of micro twisted-pair cables
- Radiation-hardness of PIN arrays
- Radiation-hardness of VCSEL arrays
- Summary

ATLAS Silicon Trackers Opto-Links

- ATLAS is a detector studying pp collisions of 14 TeV at CERN
  - silicon strip and pixel detectors are used for tracking
  - detector upgrade planned for Super-LHC in 2015
- current optical link of pixel detector transmits signals at 80 Mb/s
  - opto-links are located at ~ 1.4 m off pixel modules
  - transmit signal to/from pixel modules with micro twisted pairs
  - much reduced radiation level
  - opto-link production is decoupled from module production
  - use PIN/VCSEL arrays coupled to robust fiber ribbon

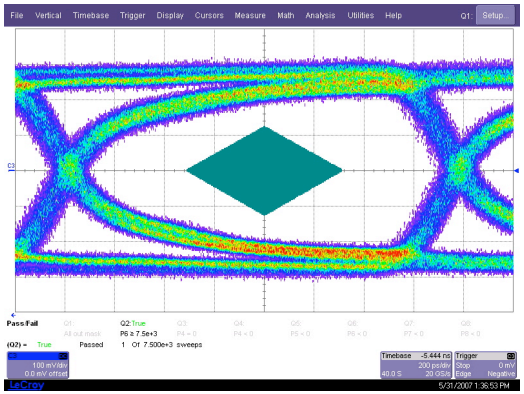
⇨ can similar architecture be used for SLHC?

- what is the bandwidth of micro twisted pairs?
- can PIN/VCSEL arrays survive?

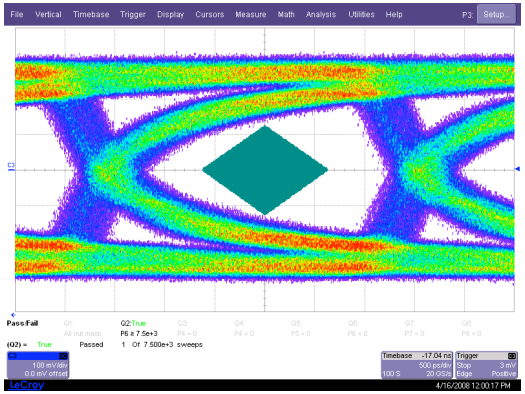
Bandwidth of Micro Twisted Pairs

current pixel cable with 100 μm diameter

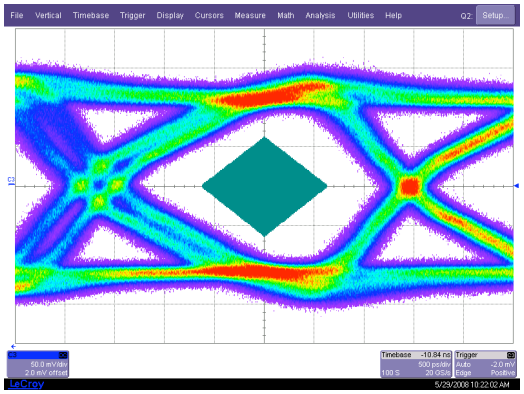
640 Mb/s
1.4 m



320 Mb/s
3 m



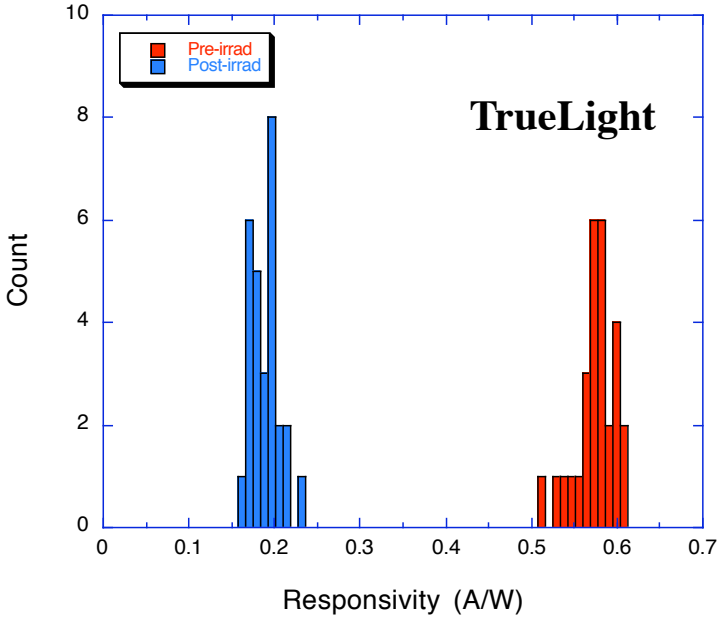
320 Mb/s
4 m

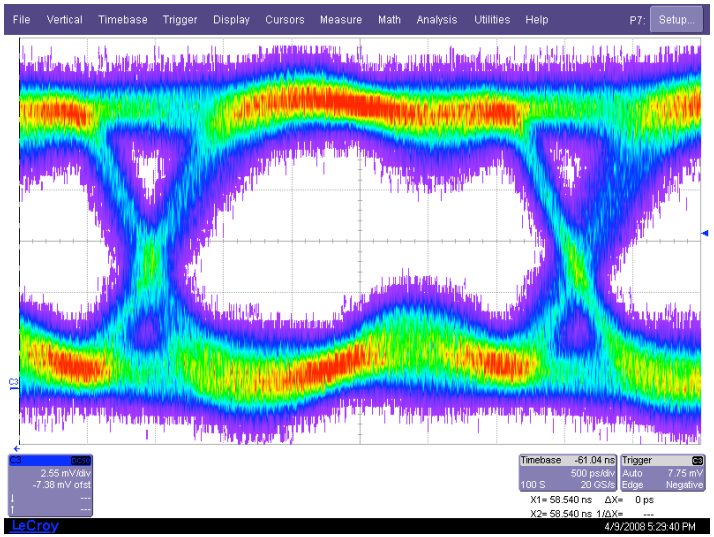


Pre-emphasis

- signals can be transmitted at 640 Mb/s up to 1.4 m
- pre-emphasis of high-frequency components in signal driver to compensate for transmission loss in long cable
  ⇨ can transmit at 320 Mb/s up to ~ 4 m

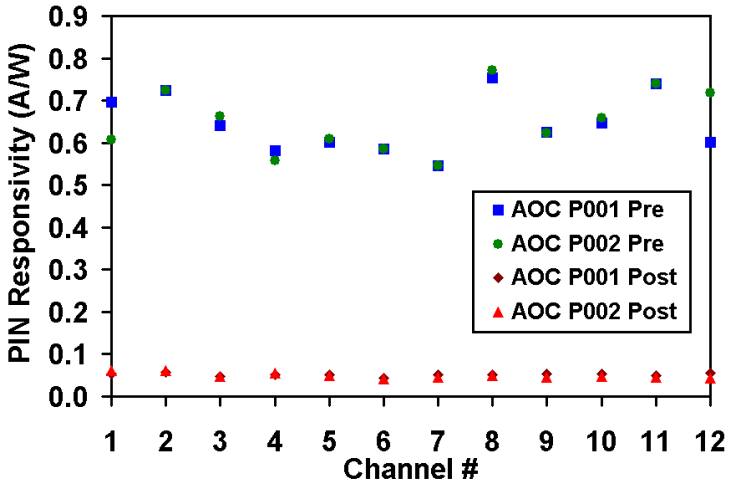
Radiation-Hardness of Silicon PIN

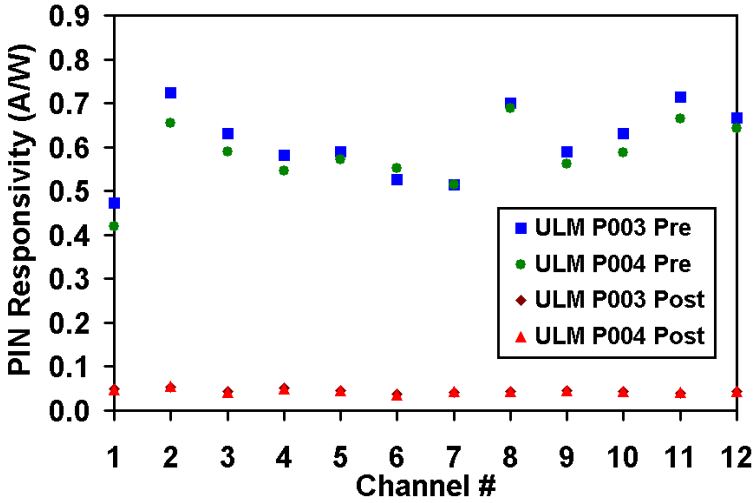


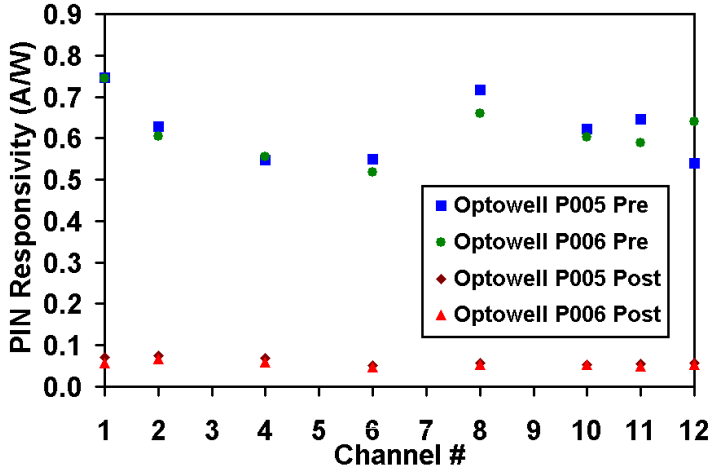


- irradiate PIN/VCSEL arrays with 24 GeV protons at CERN
- PIN responsivity decreases by 3x at 114 Mrad
  - SLHC: 69 Mrad or 1.5 x 10^{15} 1-MeV n_{eq}/cm^2 for $3{,}000^{-1}$ fb with 50% safety factor
- 320 Mb/s transmission is adequate

Radiation-Hardness of GaAs PIN

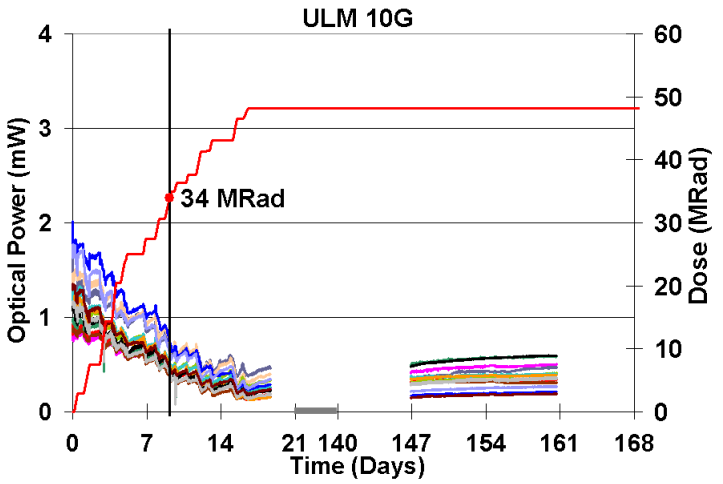


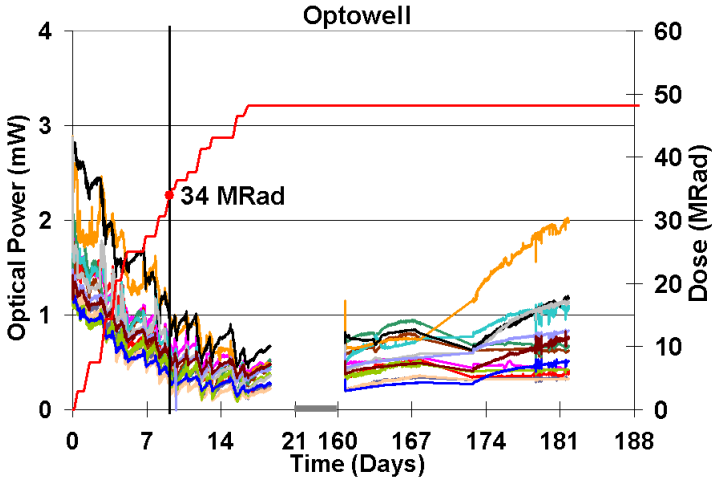


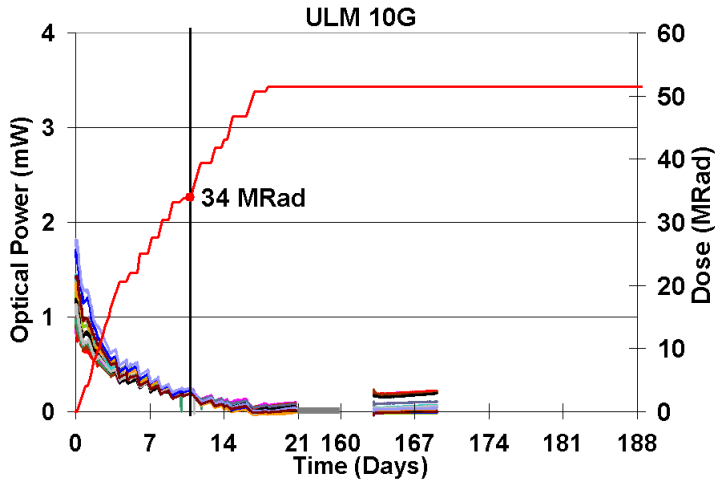


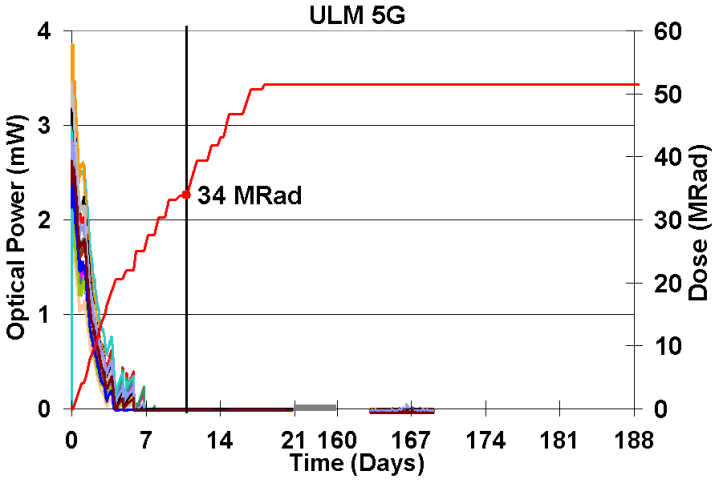
- all arrays are front side illuminated
- PIN responsivities decrease by ~10x at 53 Mrad
- should repeat irradiation to SLHC dosage of 34 Mrad (8.2 x 10^{15} 1-MeV n_{eq}/cm^2)

Radiation Hardness of VCSEL Arrays



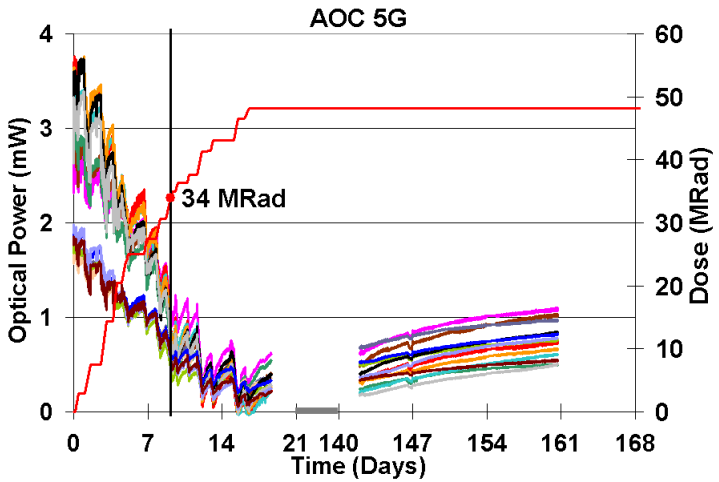


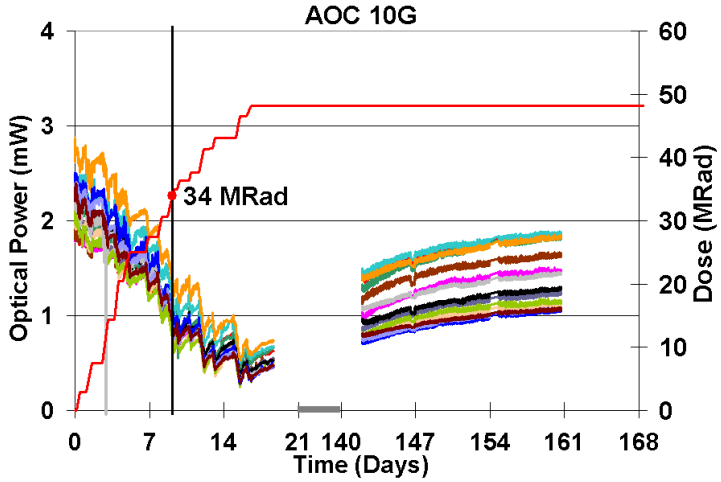


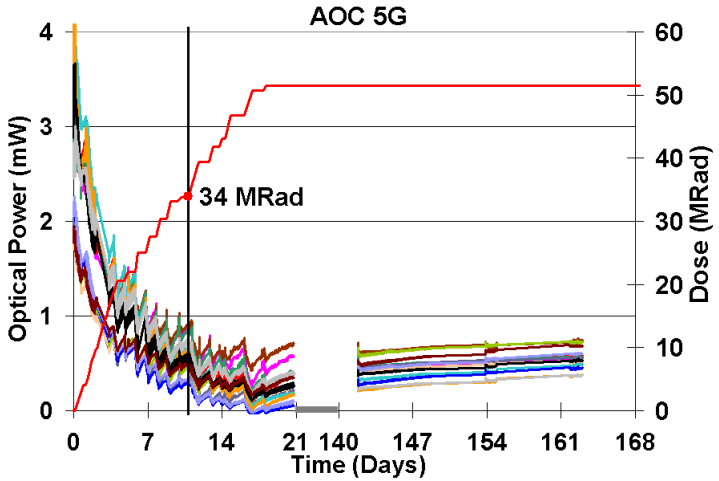


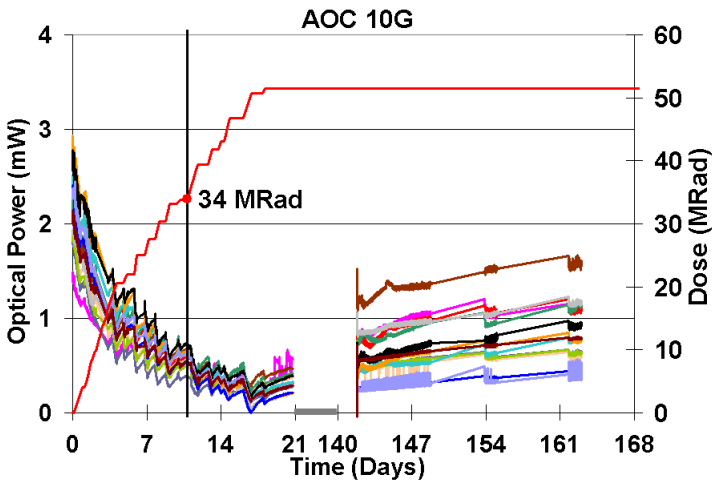
- Optowell has adequate power at SLHC dosage
- Optowell has the highest annealed power but recovery is slow

Radiation-Hardness of VCSEL Arrays





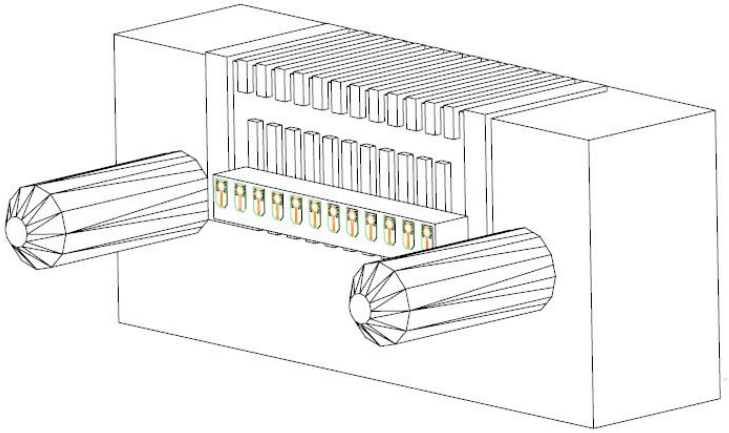


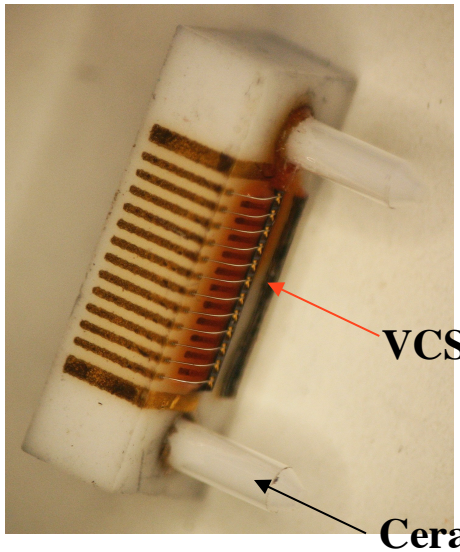


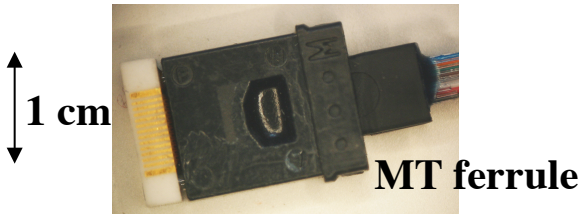
- AOC 5/10 G have adequate power at SLHC dosage
- optical power recovery by annealing is slow

Opto-Pack

- 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
  - new opto-packs have good coupled power







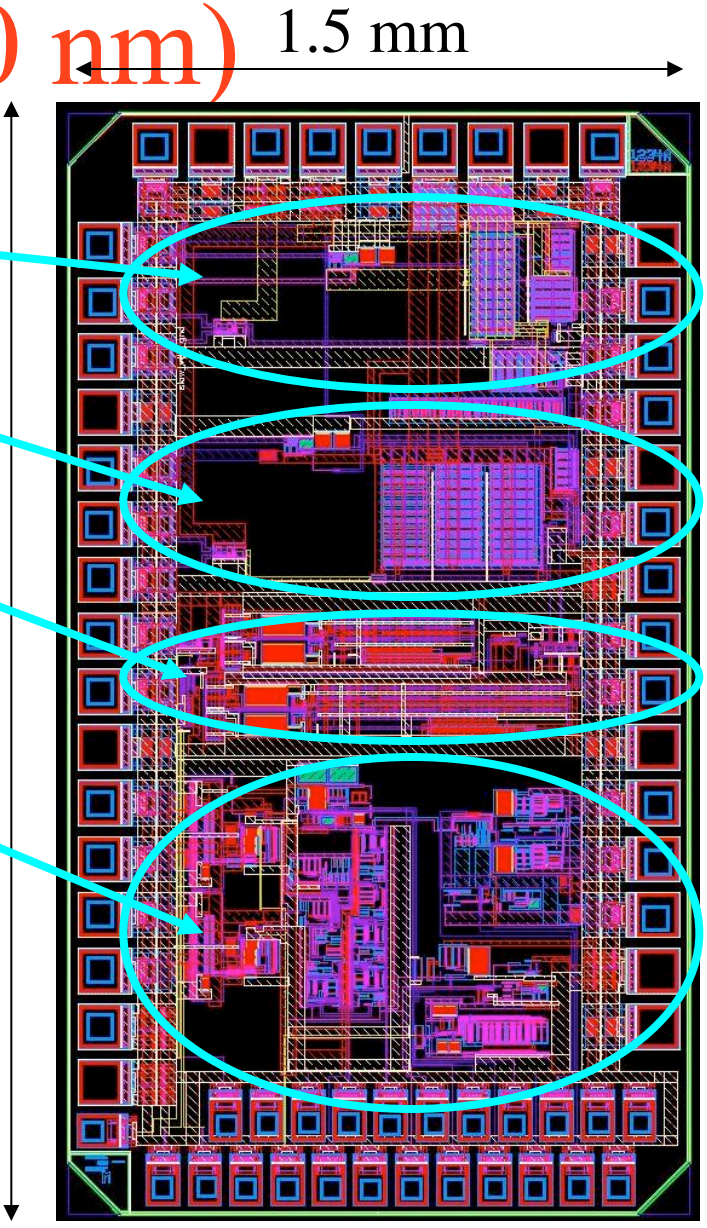
Opto-Chips (130 nm)

640 Mb/s VCSEL Driver

3.2 Gb/s VCSEL Driver

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

PIN receiver/decoder
(Decode bi-phase encoded signal
at 40, 160, and 320 MHz)



- delivery date: July 08
- irradiation: August 08
  - study radiation-hardness and single event upset (SEU) immunity

Summary

- micro twisted-pair cables can transmit signals
  at several hundred Mb/s up to several meters
- silicon PIN array can survive in harsh SLHC radiation environment
  - degradation of GaAs device is unacceptable for SLHC application
- VCSEL arrays from two vendors
  can survive in harsh SLHC radiation environment
- ASIC for optical link applications has been designed
  - radiation-hardness/SEU immunity will be evaluated in August