High-Speed/Radiation-Hard Optical Links

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Outline

- Introduction
- Opto-pack design
- Opto-board design
- Results from first prototype opto-board

Use of VCSEL Arrays in HEP

- Widely used in off-detector (no radiation) data transmission
- First on-detector implementation in pixel detector of ATLAS
  - experience has been positive
    - ⇨ use arrays for the second generation opto-links
    - ⇨ logical for HL-LHC ATLAS pixel detector to use 12-channel arrays as in the 1st and 2nd generation opto-boards

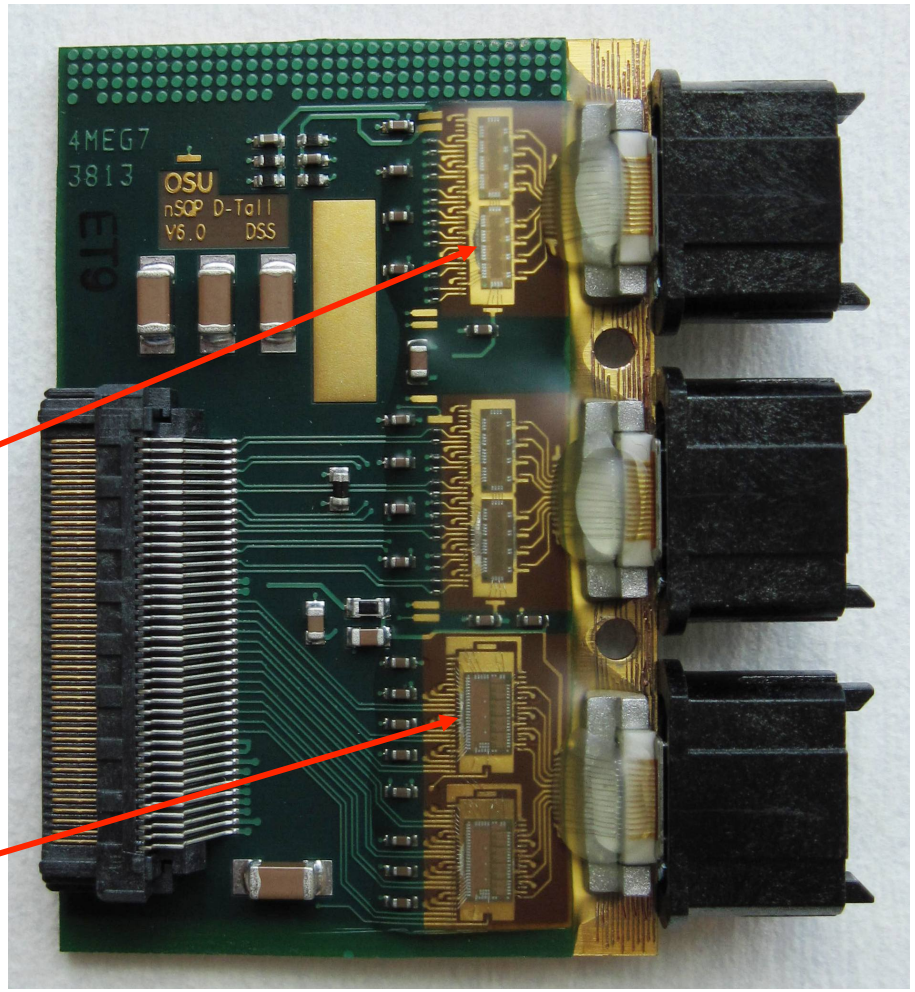
Opto-Links of Pixel Detector

- Built two generations of opto-links for the pixel detector
  - pixel detector initially has 3 barrel layers + 3 disks on each side
    - opto-links built by OSU had ~0.1% broken links
  - added insertable barrel layer (IBL) in 2014
    - move opto-links to more accessible location
    - 300 opto-modules (opto-boards) are needed
      - ~6,000 opto-links
      - fabricated 400 opto-boards

Opto-Board for HL-LHC ATLAS Pixel Detector

- Use experience from building two generations of opto-boards to develop an opto-board capable of operation at 5 Gb/s or higher for HL-LHC ATLAS pixel detector (ITK-Pixel)
- What is required to demonstrate that the opto-board concept is a logical solution?
  - 5 Gb/s per channel VCSEL arrays
  - radiation-hard VCSEL array driver
  - robust high speed array based packaging with thermal management
- A working prototype has been constructed

2nd Generation Pixel Opto-Board



driver

receiver

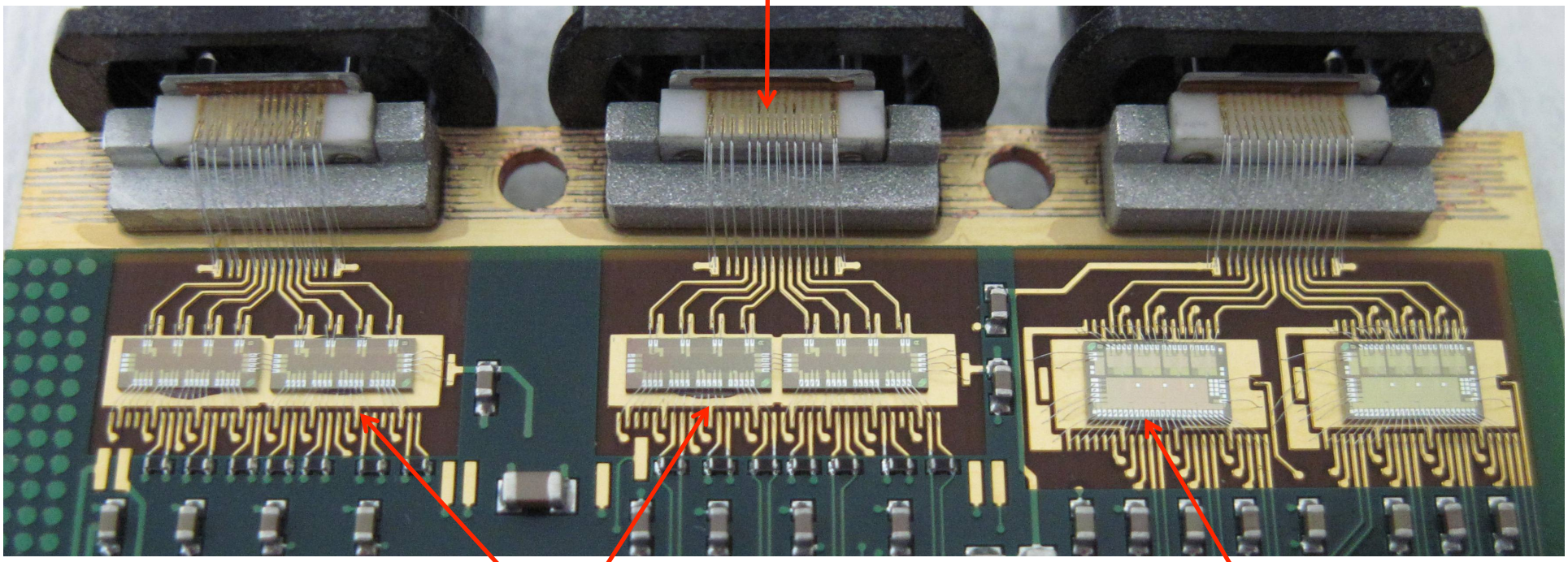
VCSEL

VCSEL

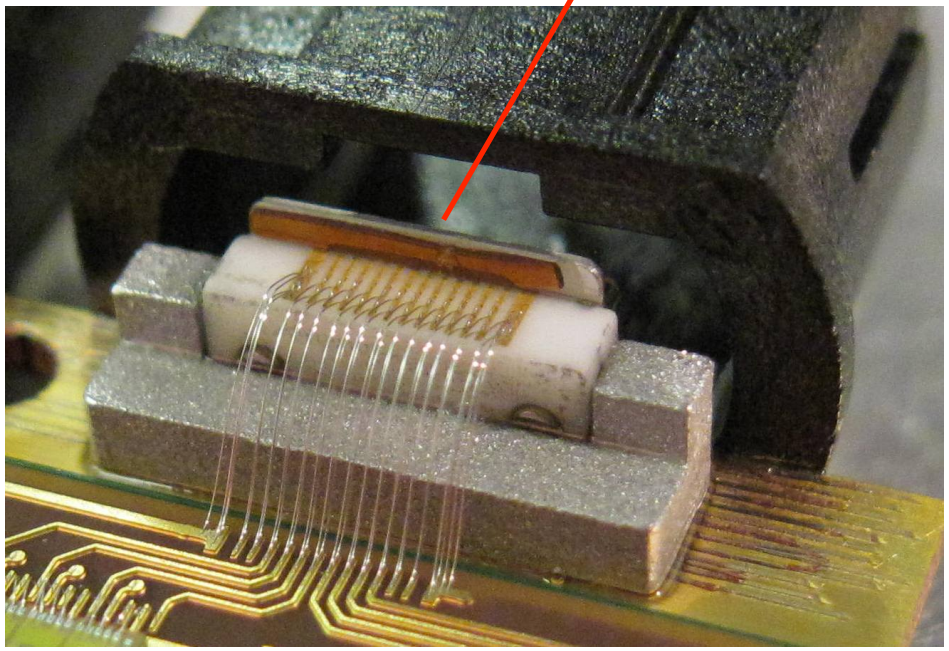
PIN

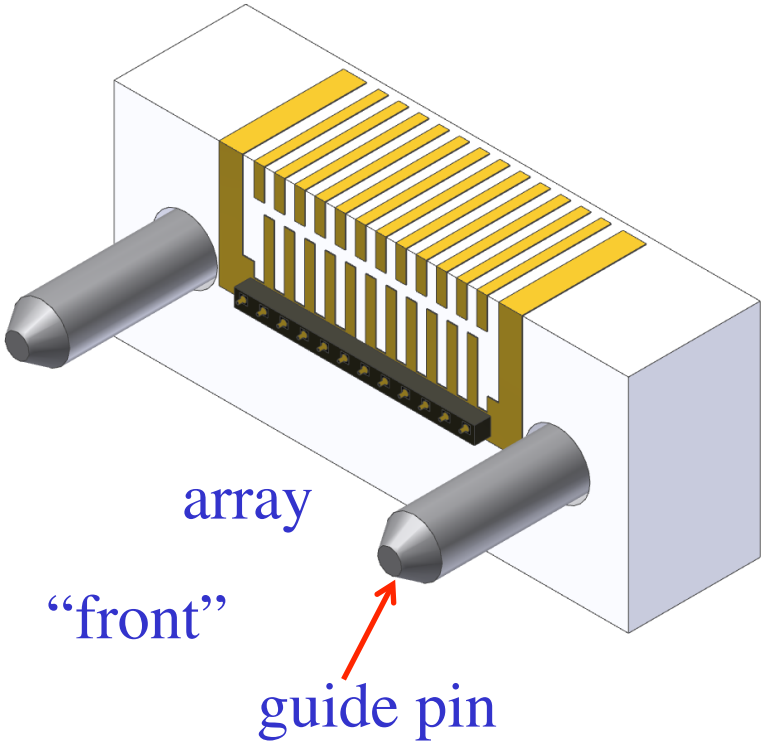
3 cm

Close Up View



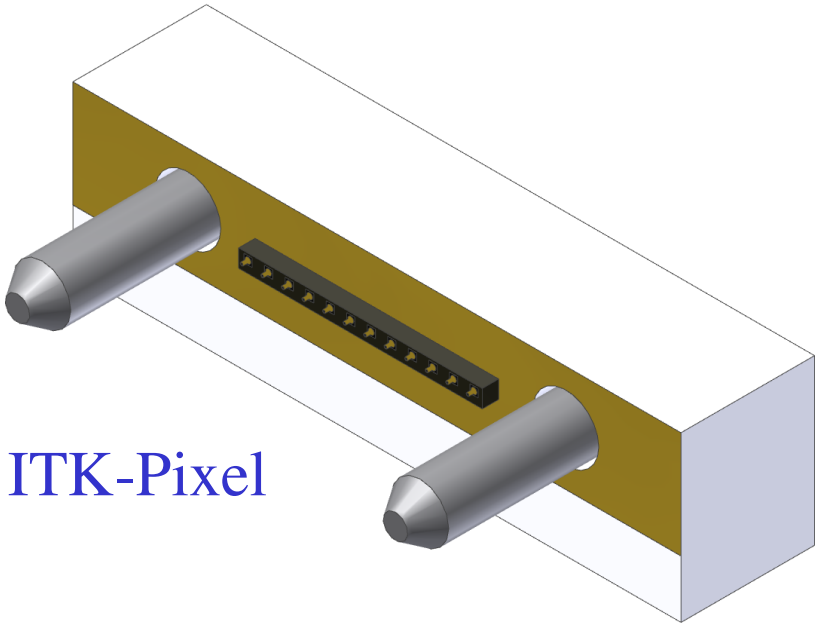
Opto-Pack



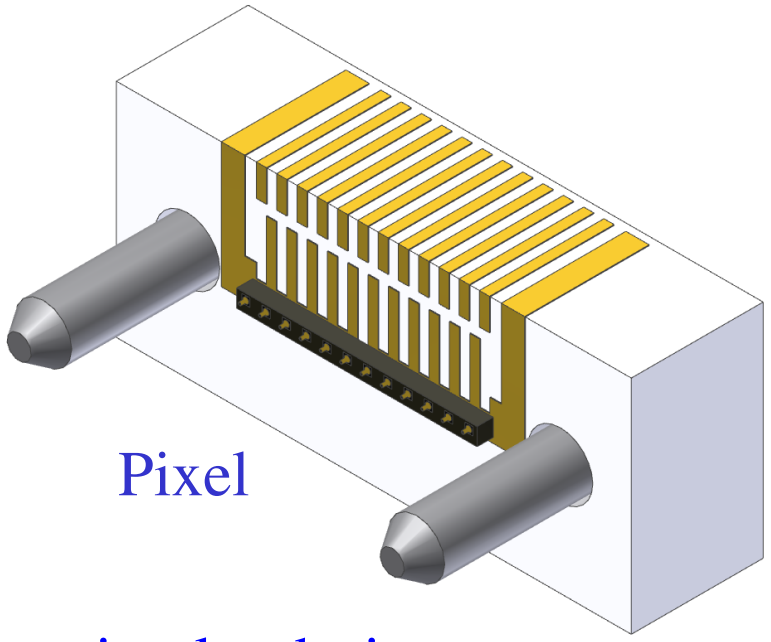


- Use BeO as substrate for heat management

Opto-Pack for ITK-Pixel



ITK-Pixel

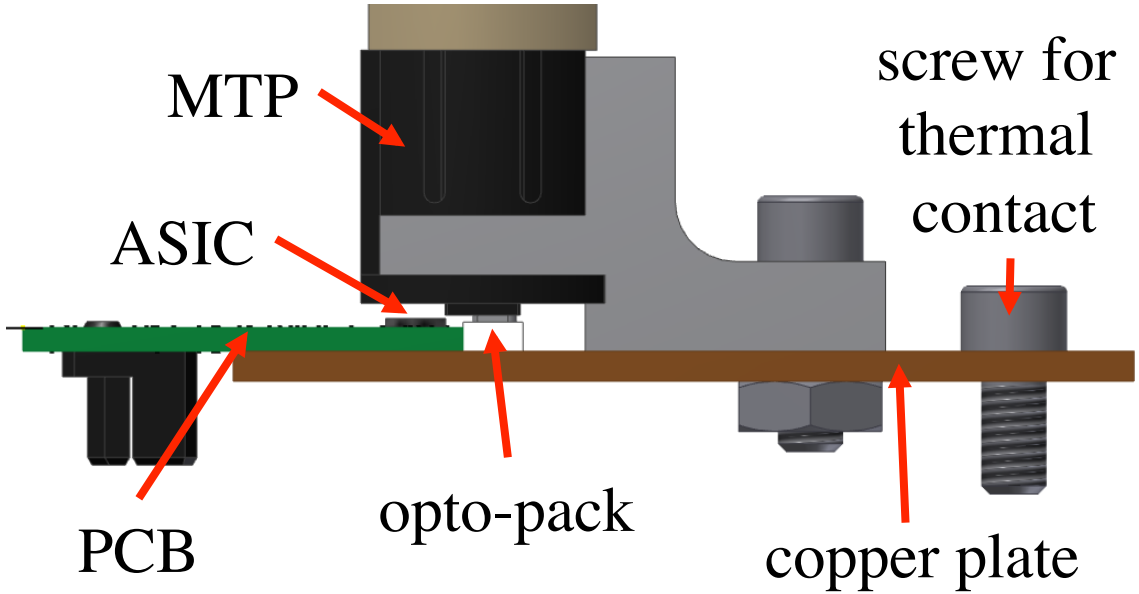


Pixel

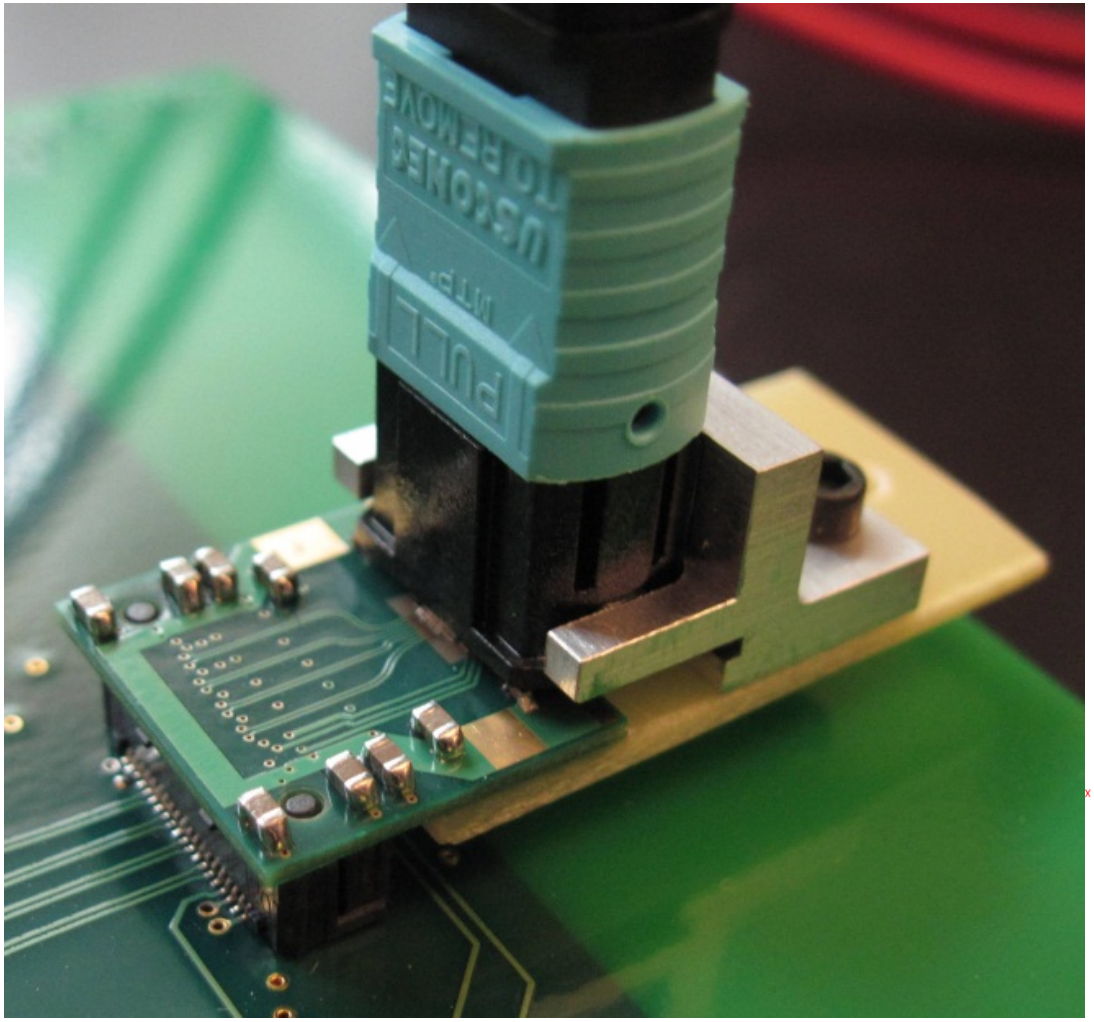
- Proposed opto-pack for ITK-Pixel has simpler design
- experience in building large quantity of opto-packs:
  - fabricated 1,200 opto-packs for pixel opto-boards
  - fabricating 280 PIN opto-packs for off-detector opto-receivers
  - equivalent to 18,000 channels

ITK-Pixel Opto-Board Concept

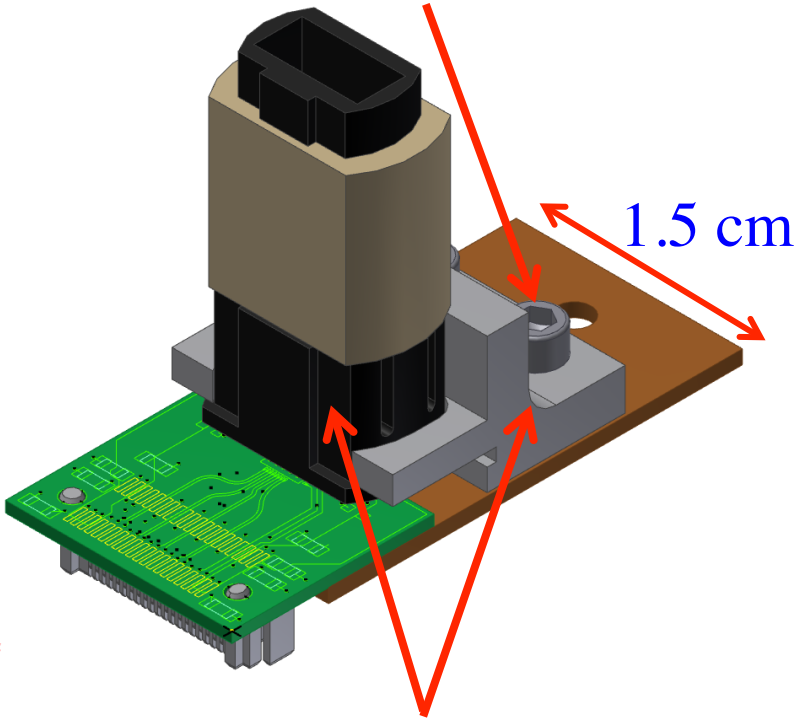
- Keep opto-pack
- Keep copper backed PCB
- Keep MTP connector
- Compatible with an opto-box (opto crate) concept
- No lenses/mirrors used to turn the light



IBL-Pixel Opto-Board (Version -1)



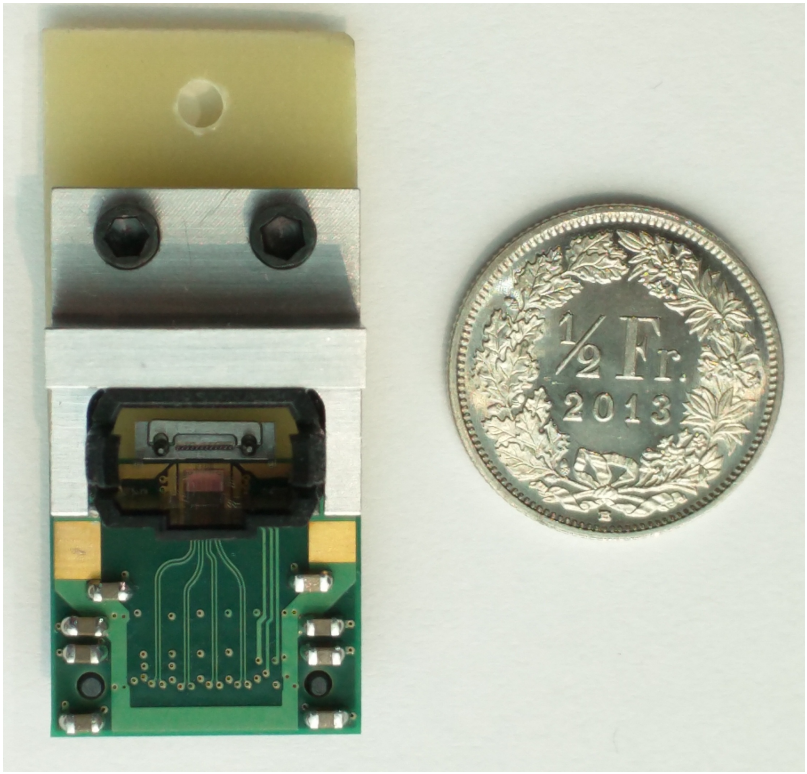
Connector secured to opto-board with screws instead of epoxy in current opto-board

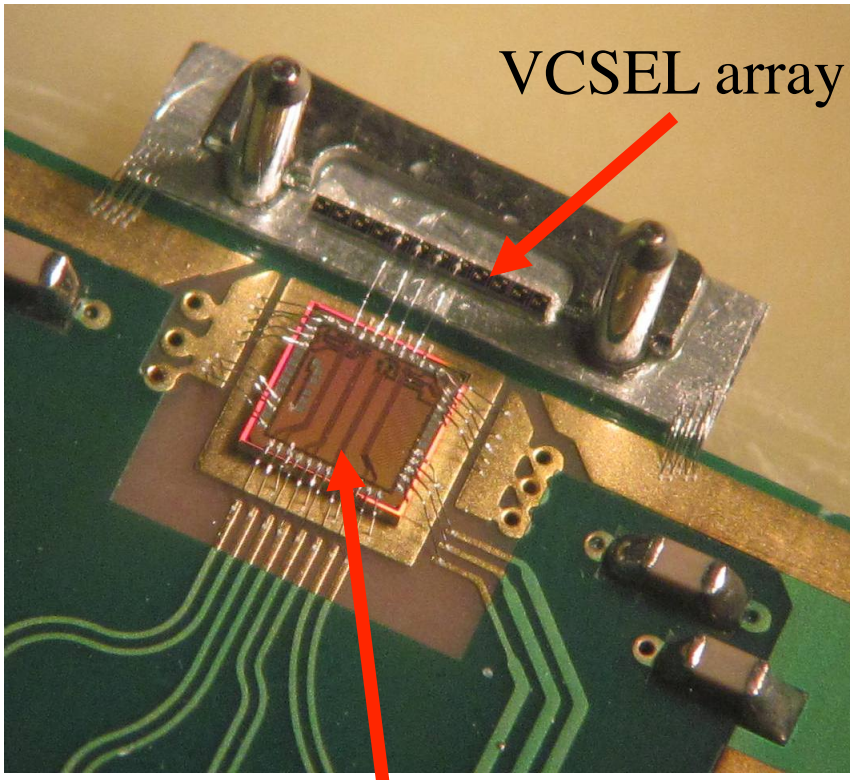


Could be fabricated as one piece with mold injection

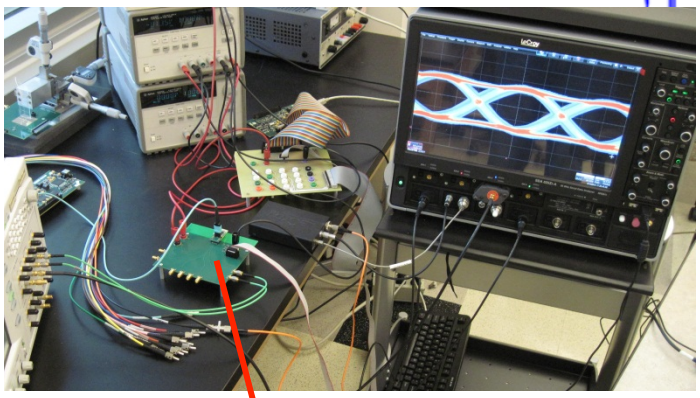
ITK-Pixel Opto-Board

- Produced a 4-channel opto-board using our array driver ASIC
  - Scalable to 12 channels by simply replacing the ASIC
- Uses a Finisar 12-channel VCSEL array (V850-2174-002)

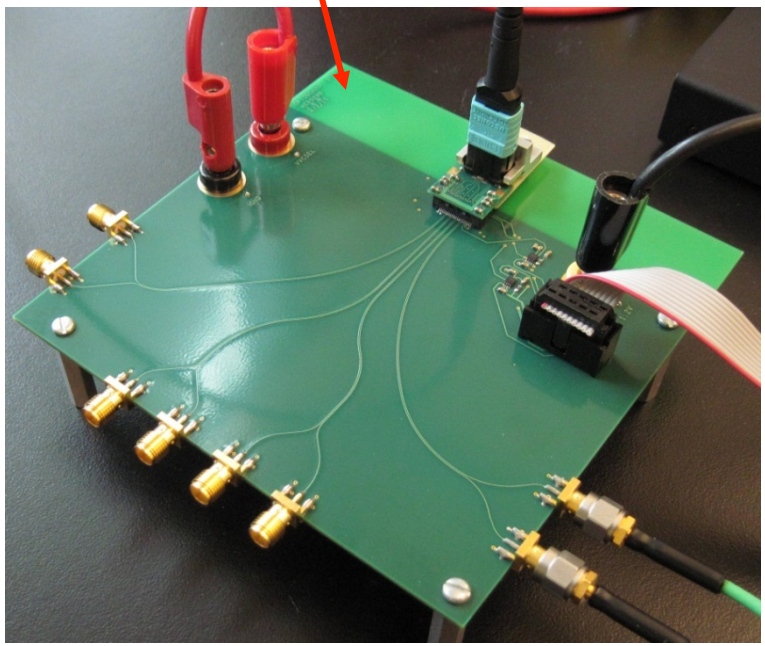




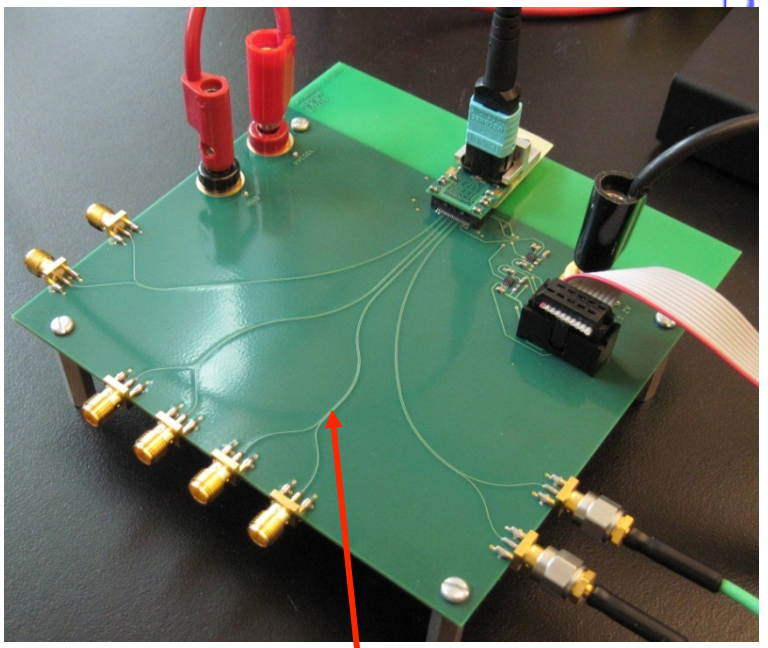
ITK-Pixel Opto-Board



- runs at 1.2 V
  - with all four channels operating consumes ~150 mA at 5 Gb/s
- cathode set to -1.3 V (~20 mA) to provide enough headroom to drive the VCSEL
- optical power > 2 mW on all channels
- BER <1x10^{-13} on all channels at 5 Gb/s with every channel active

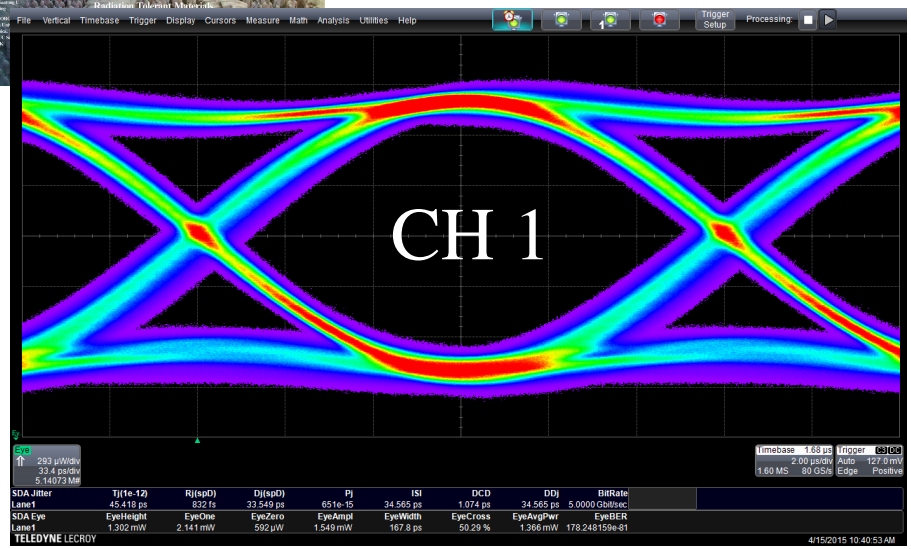


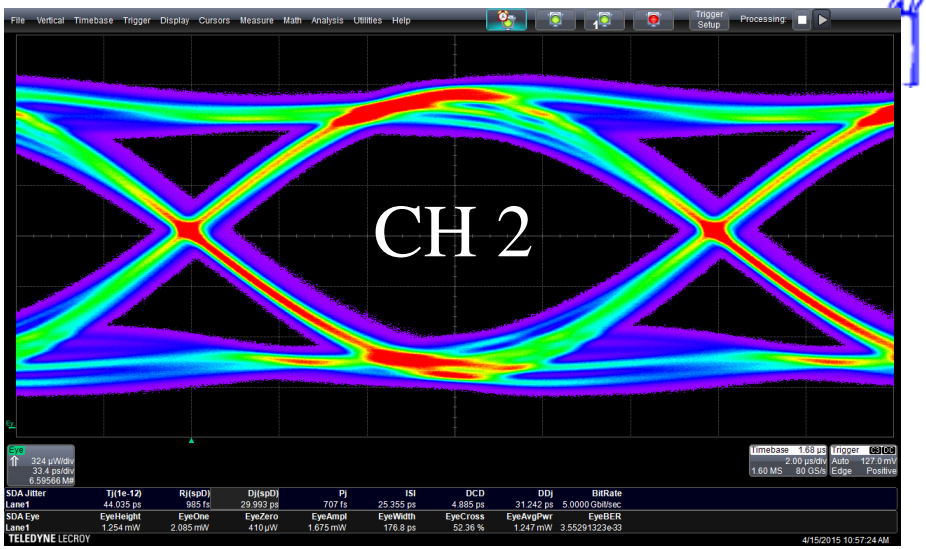
Back-Plane inside Opto-Box

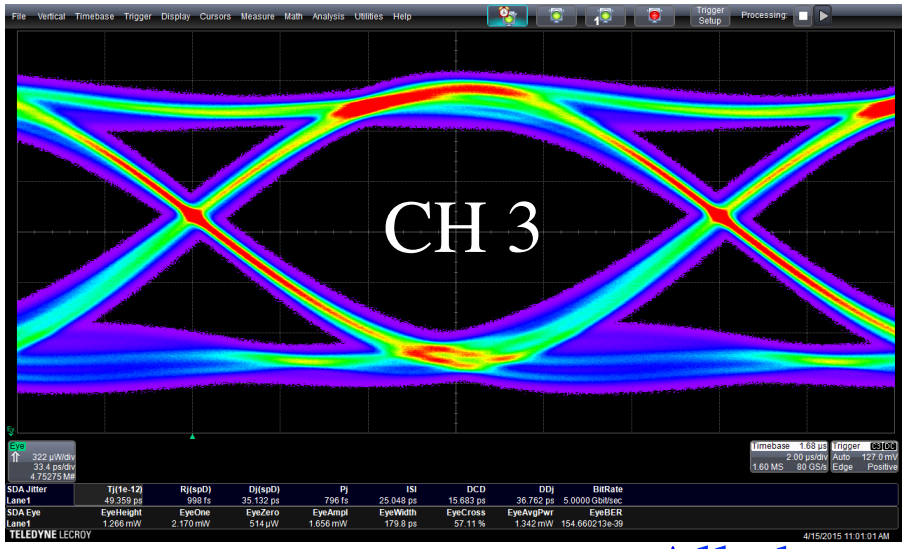


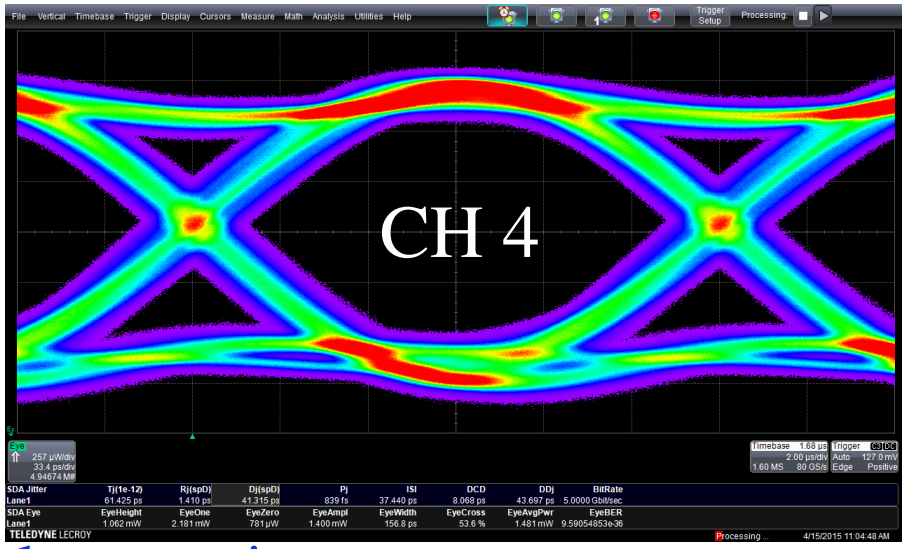
- use 175 μm space/trace controlled impedance transmission lines
- successfully transmit 5 Gb/s signals via Samtec LSHM connectors
  - ⇨ no need to connect high-speed cables directly to opto-board
  - ⇨ connect high-speed cables to "back-plane" inside opto-box

Eye Diagrams at 5 Gb/s









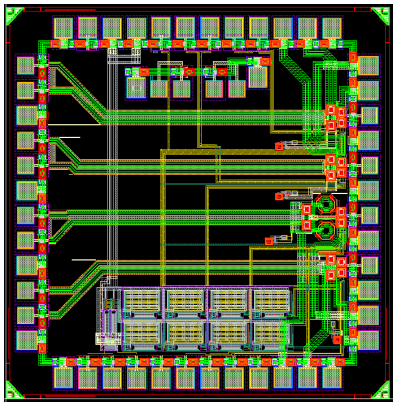
- All channels are active

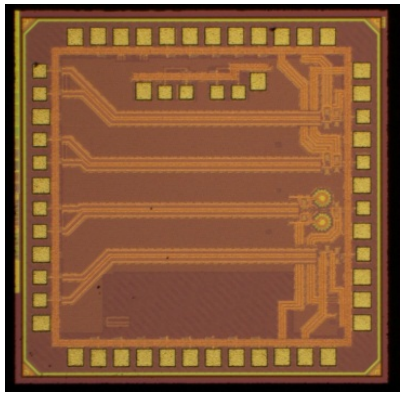
10 Gb/s VCSEL Array Driver

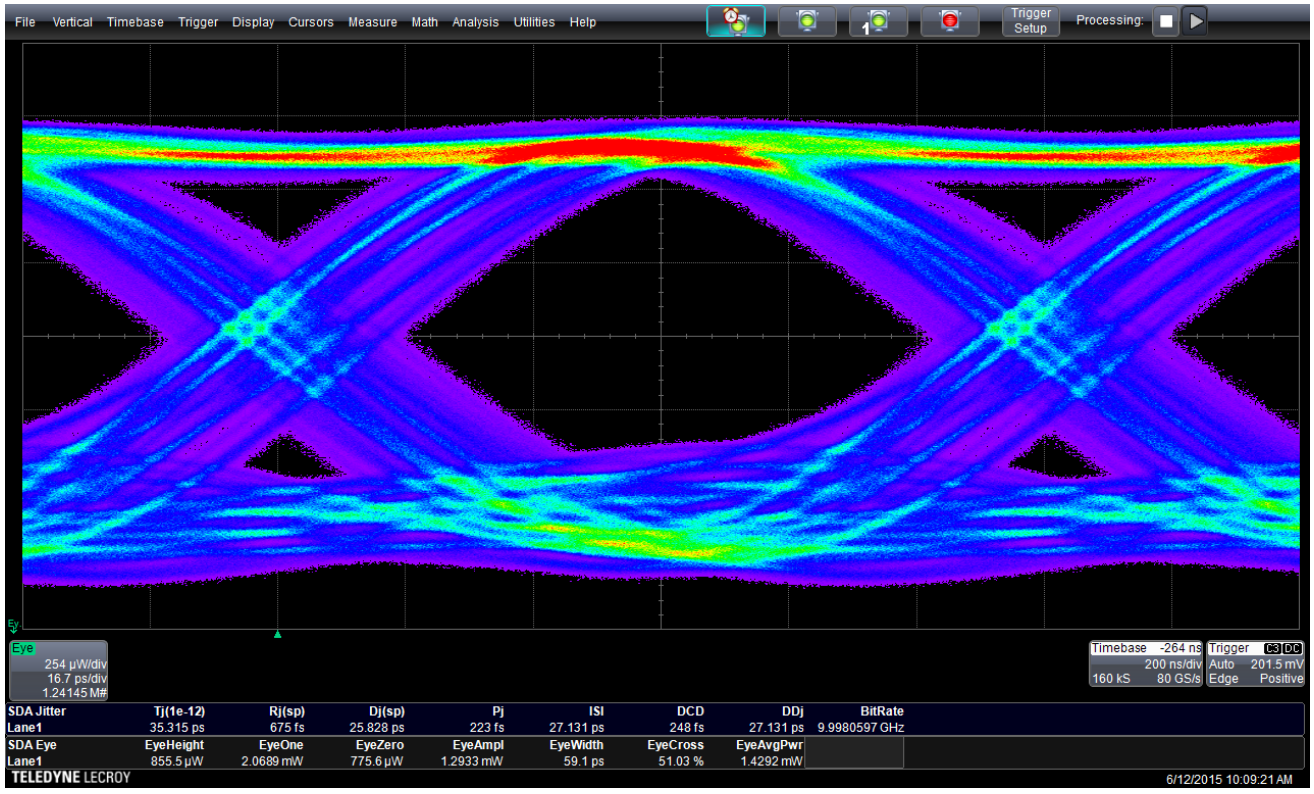
- R&D funded via CDRD (FY13-15)
- 4-channel test chip submitted in October 2014 (65 nm CMOS)
  - 2 mm x 2 mm
  - Each channel slightly different to explore design choices
- Uses only core transistors to achieve maximum radiation-hardness
- Includes 8-bit DACs to set the VCSEL modulation and bias currents
- DAC settings stored in SEU tolerant registers

Eye Diagram at 10 Gb/s

- Eye diagram at 10 Gb/s is open but improvement is needed
  - Bit error bit: 1.3×10^{-15}







Summary

- high-speed/radiation-hard parallel optical engine
  - successfully designed and prototyped for HL-LHC ATLAS Pixel detector
  - include an ASIC and optical packaging
  - satisfactory performance for 5 Gb/s optical data transmission