Results on
ITK-Pixel Optical Links R&D

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Outline

- **Introduction**

- **ITK-Pixel opto-board design**

- **ITK-Pixel opto-pack design**

- **Results from first prototype opto-board**

Proposed ITK-Pixel Opto-Board

● Use experience from the original pixel, nSQP, and IBL,

to develop an opto-board capable of operation at 5 Gb/s

or higher for ITK-Pixel

● What is required to demonstrate that the opto-board concept

is a logical solution for ITK-Pixel?

 ■ 10 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

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

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
- Versatile Links now developing 4-channel array links
    - more logical for ITK-Pixel to use 12-channel arrays
      as in the 1st and 2nd generation opto-boards
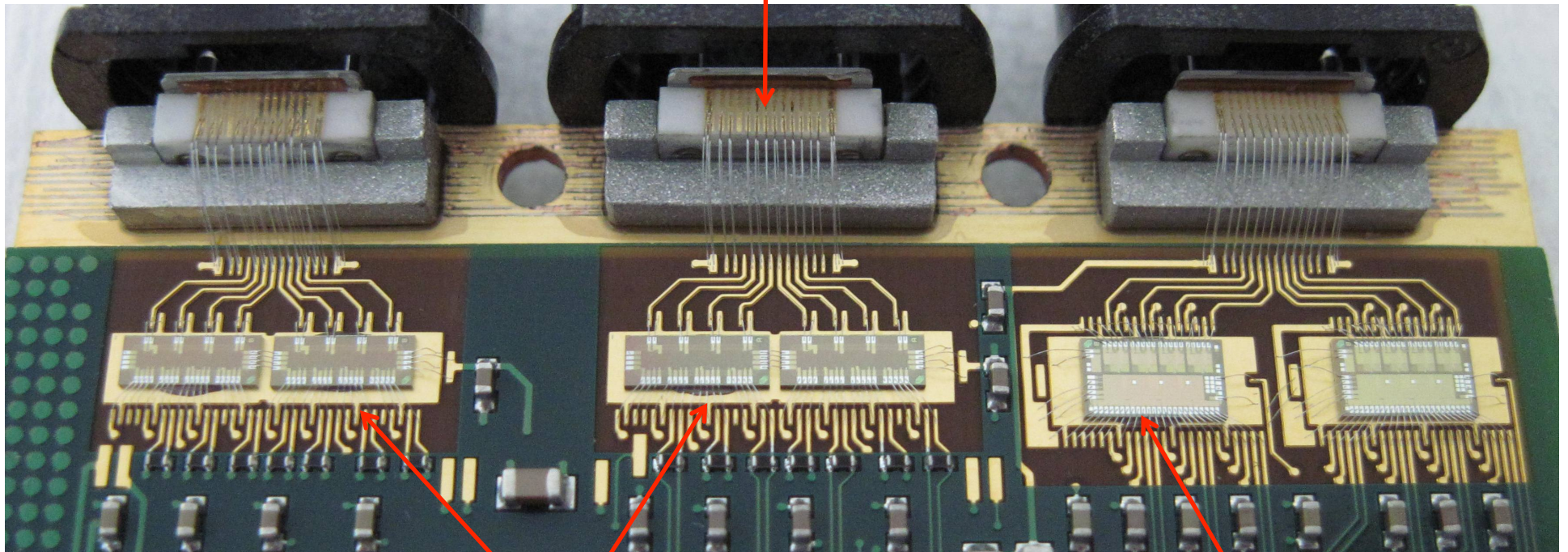   - build 3 x times fewer modules with 12-channel arrays

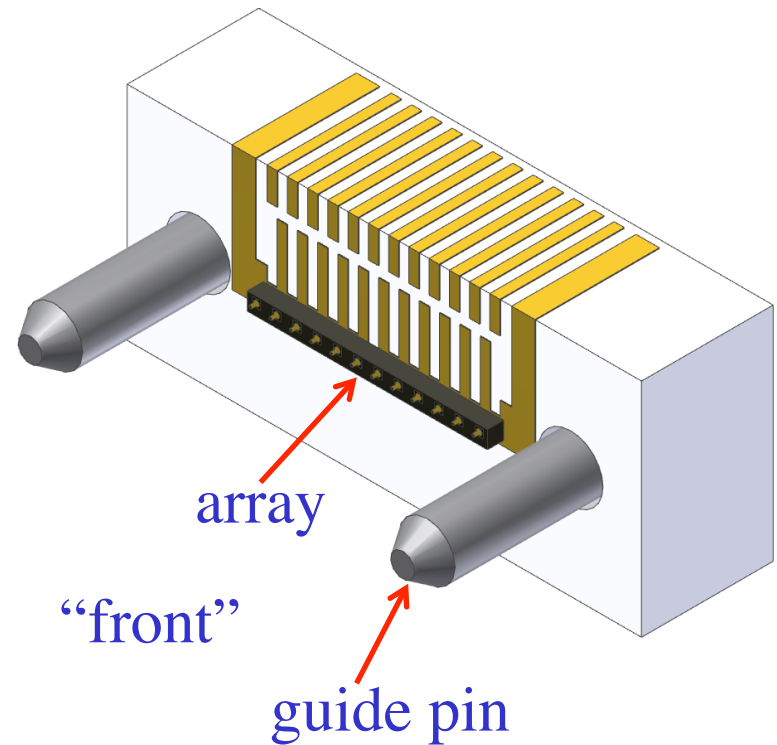# 2ⁿᵈ Generation Pixel Opto-Board

VCSEL

VCSEL

PIN

driver

receiver

3 cm
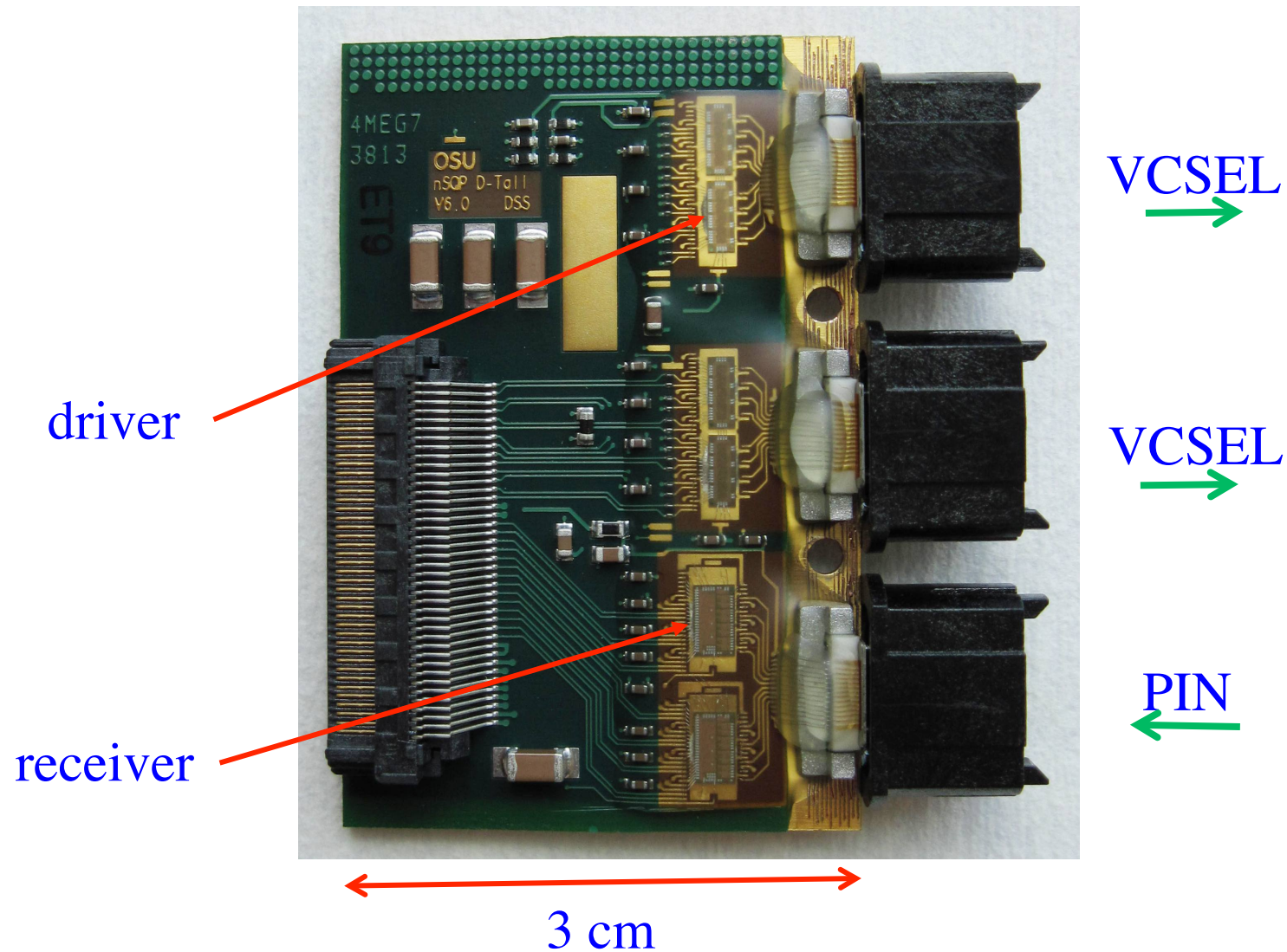
Close Up View

Opto-pack

VDC
(VCSEL driver)

DORIC
(PIN receiver/decoder)
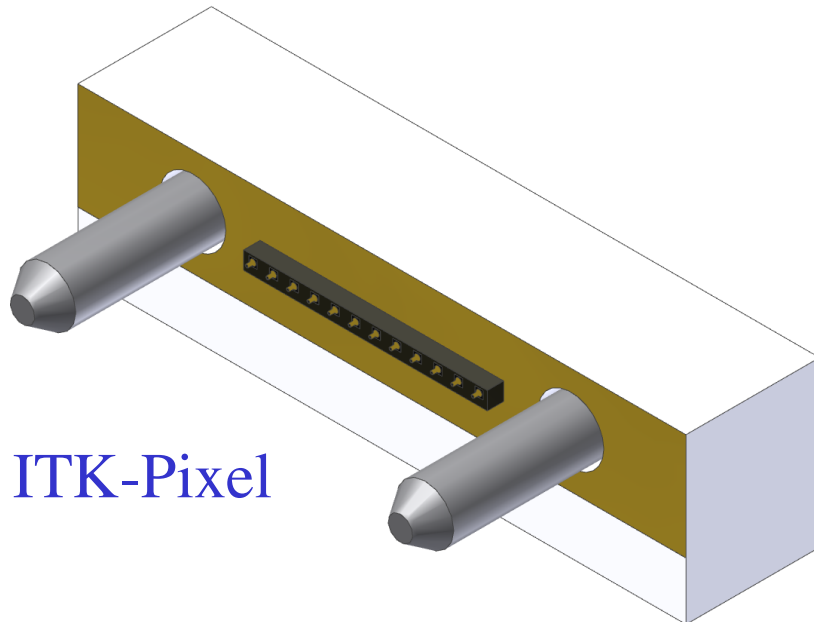
Opto-Pack

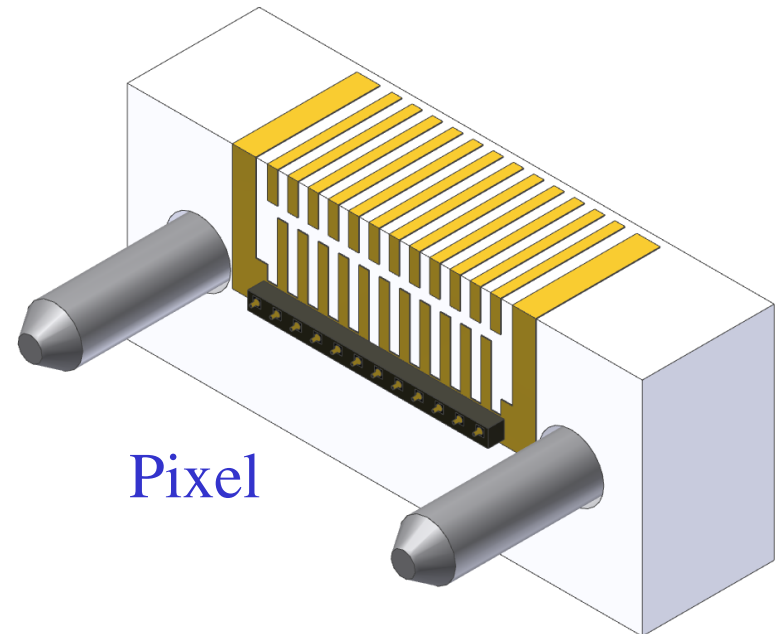"back"

array

"front"

guide pin
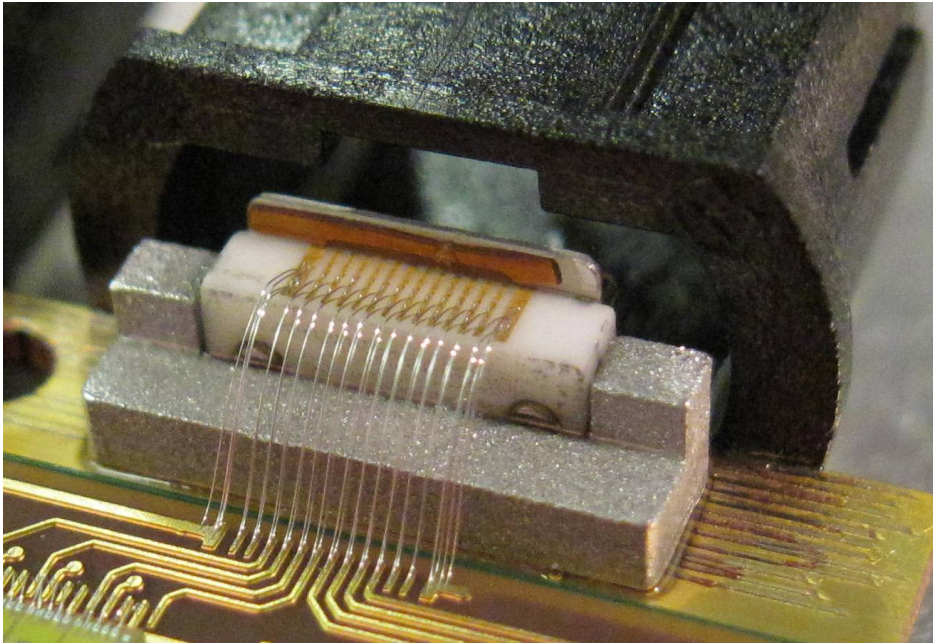
- Use BeO as substrate for heat management

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
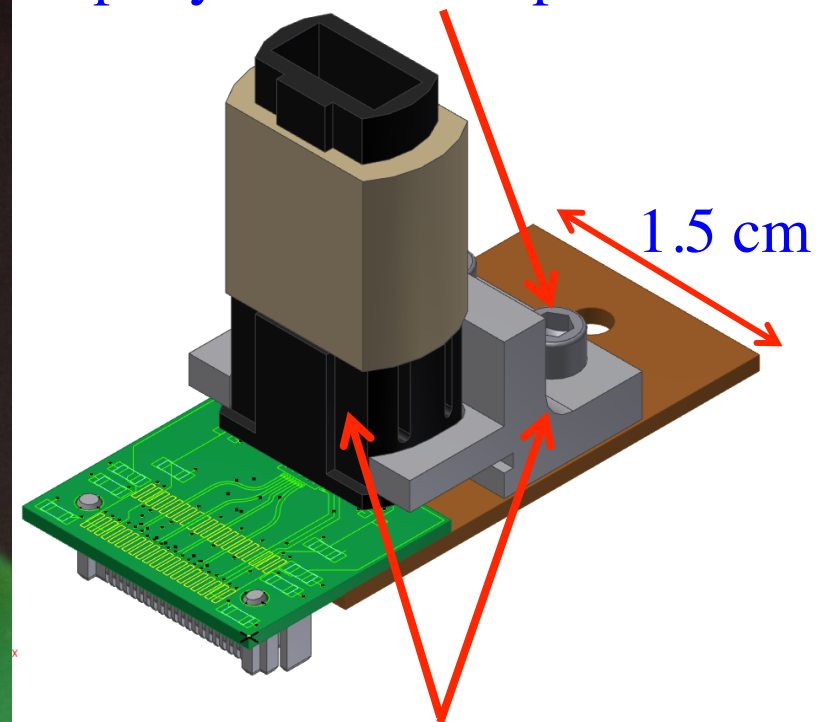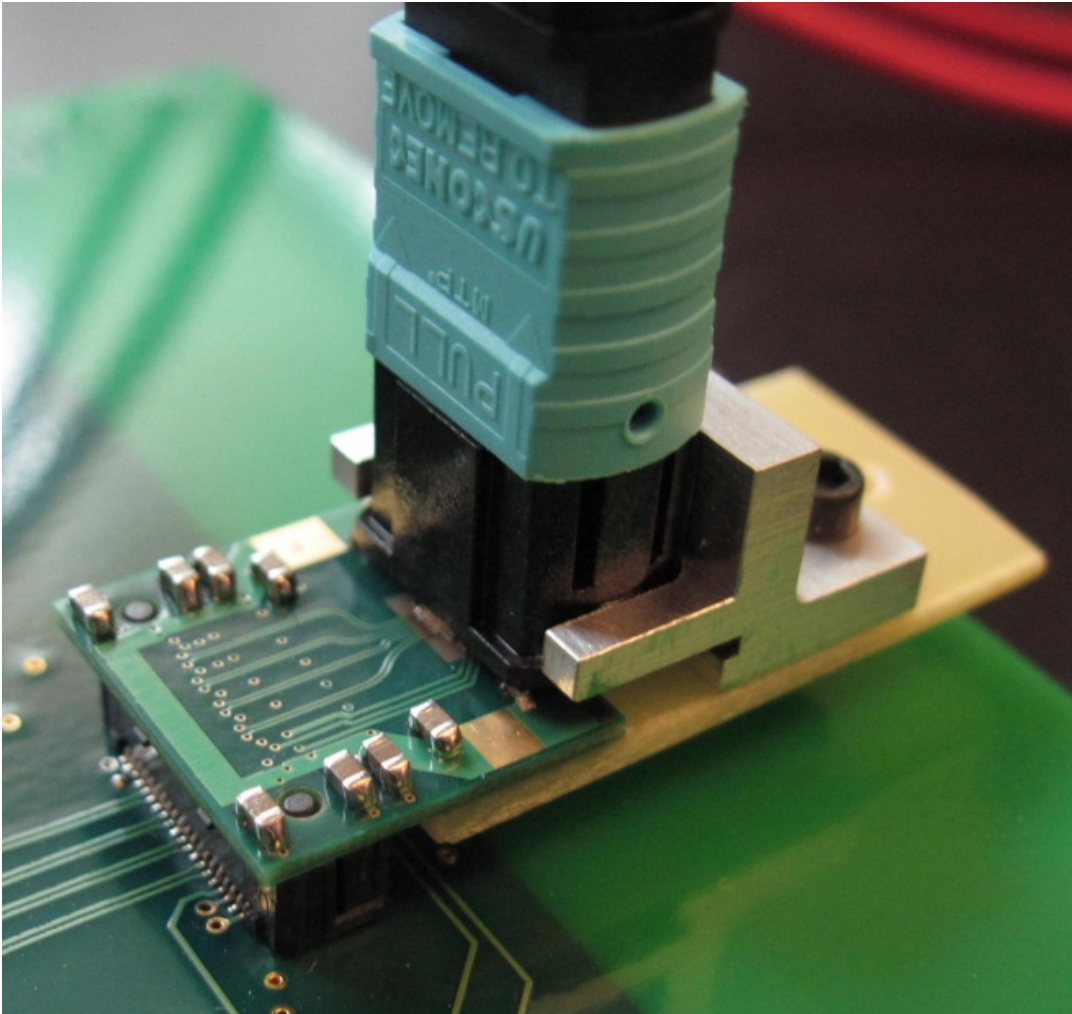
ITK-Pixel Opto-Board Concept

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

MTP

ASIC

screw for thermal contact

PCB

opto-pack

copper plate
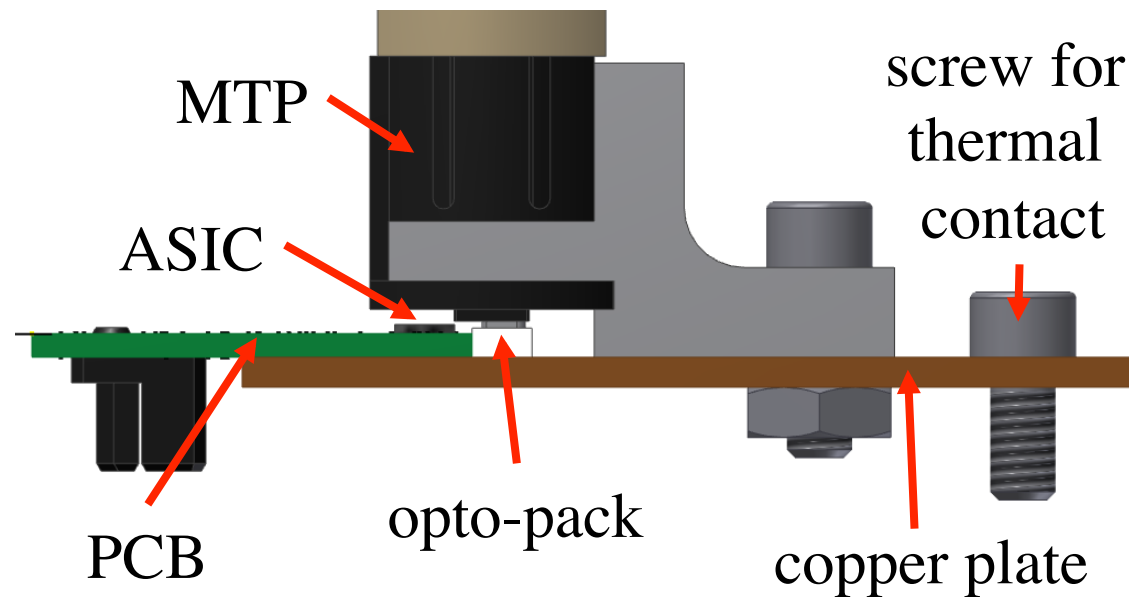
ITK-Pixel Opto-Board (Version -1)

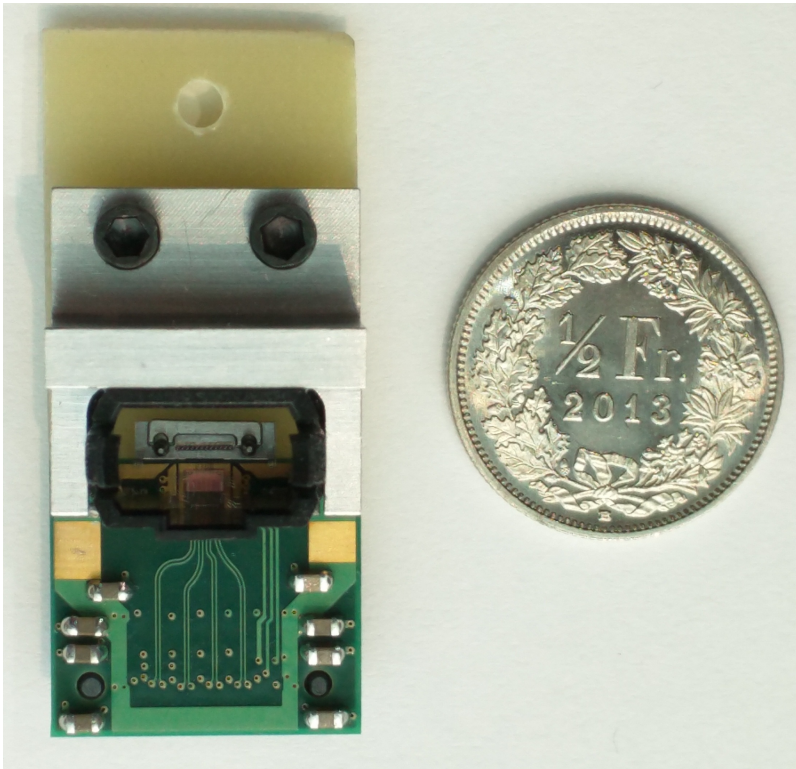Connector secured to opto-board with screws instead of epoxy in current opto-board

1.5 cm

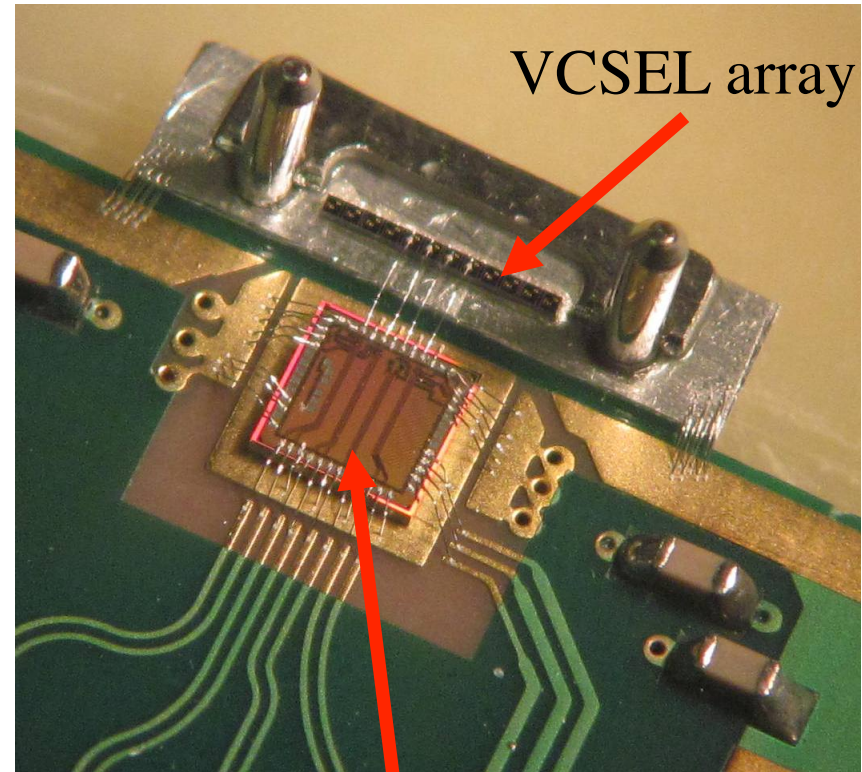Could be fabricated as one piece with mold injection

ITK-Pixel Opto-Board

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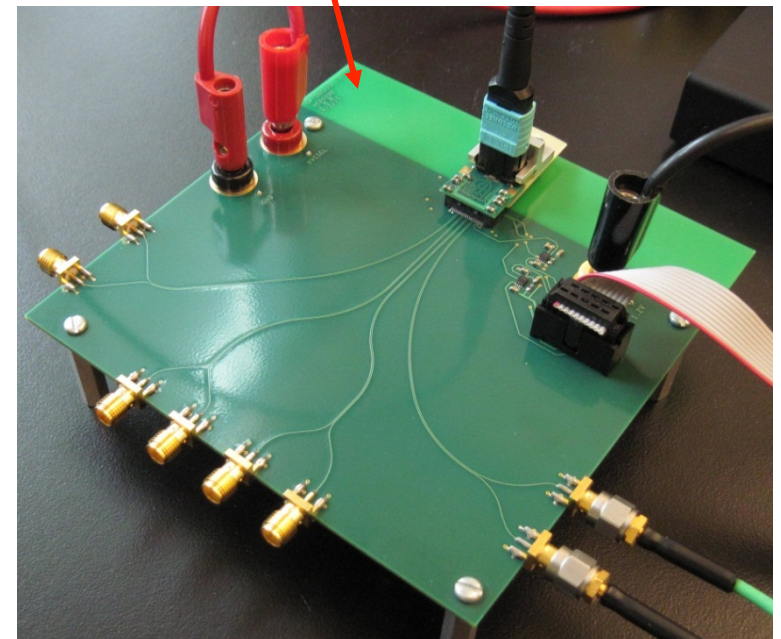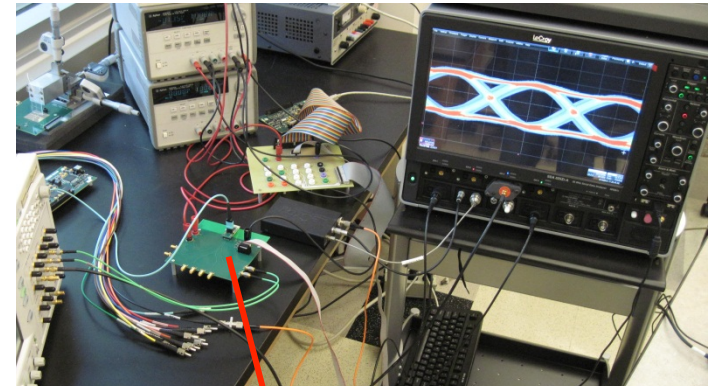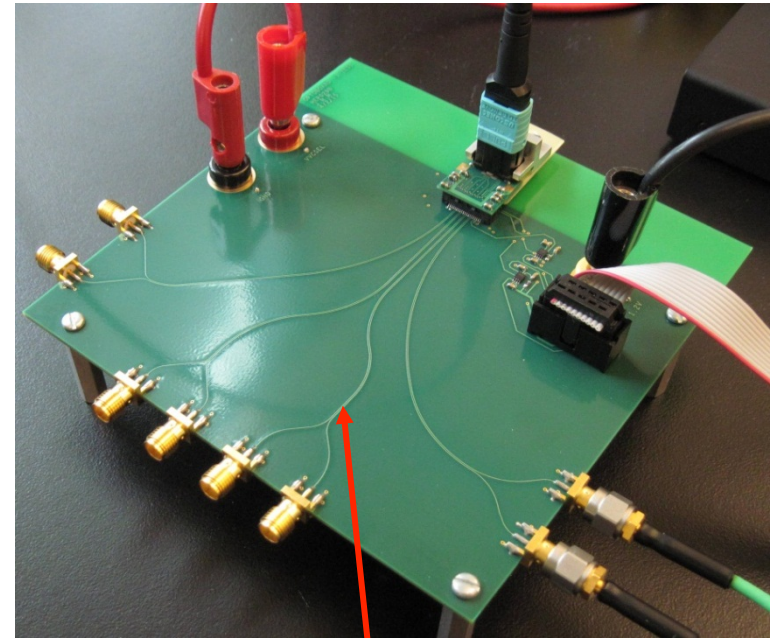- Uses a Finisar 12-channel VCSEL array (V850-2174-002)

VCSEL array

ASIC

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
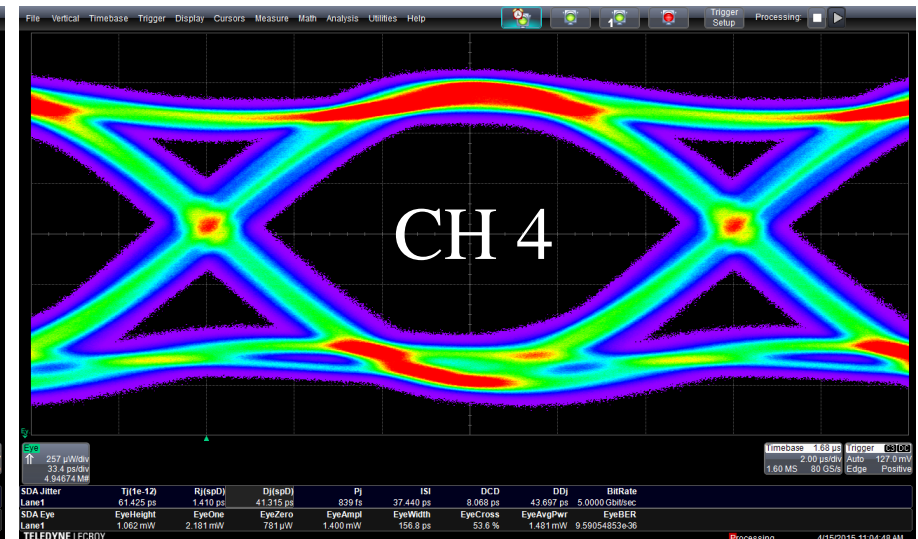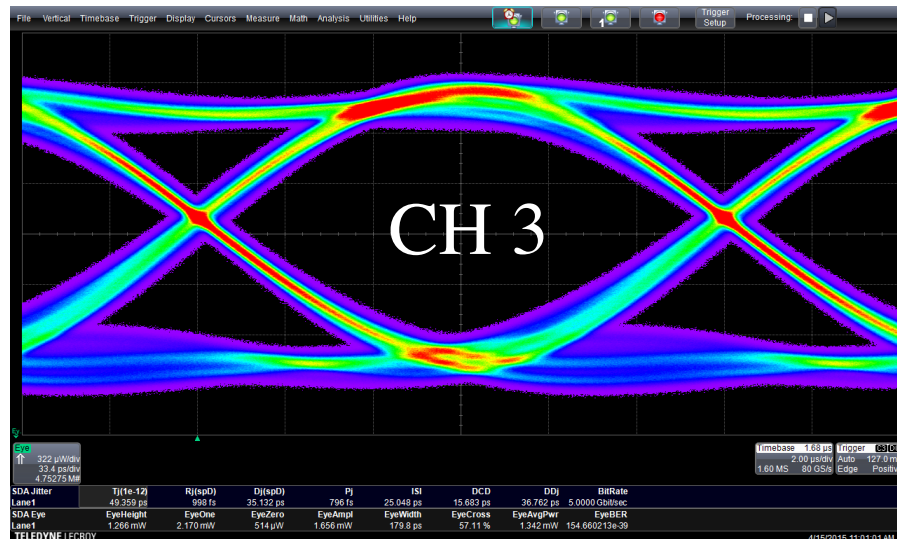- BER $<1 \times 10^{-13}$ on all channels at 5 Gb/s with every channel active
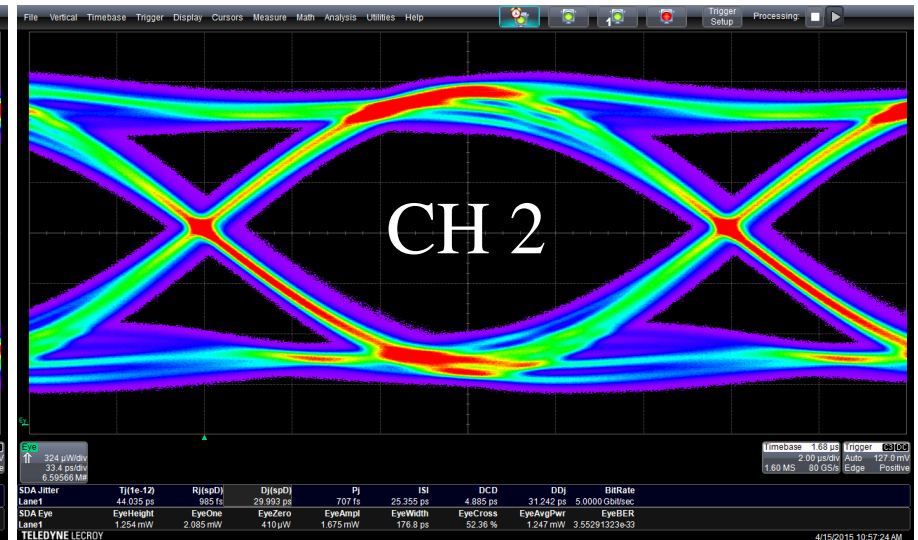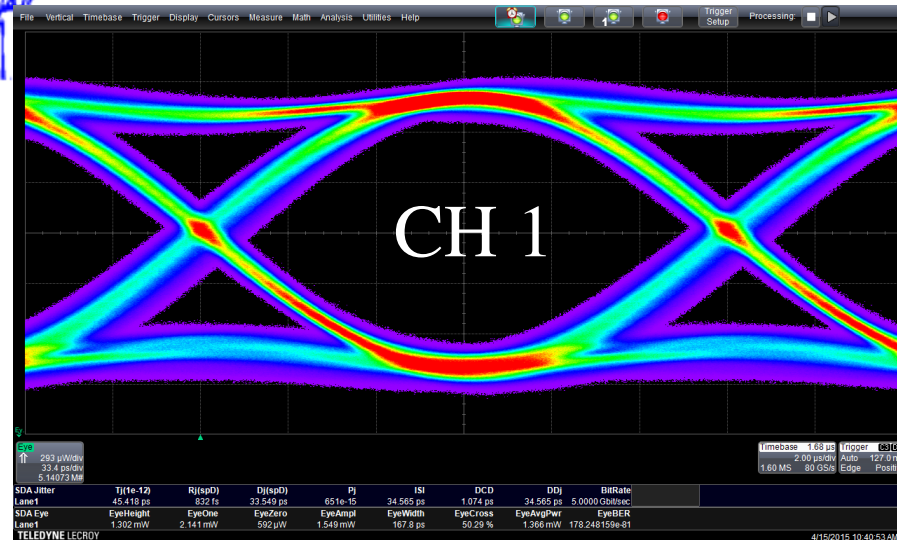
Back-Plane inside Opto-Box

- 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
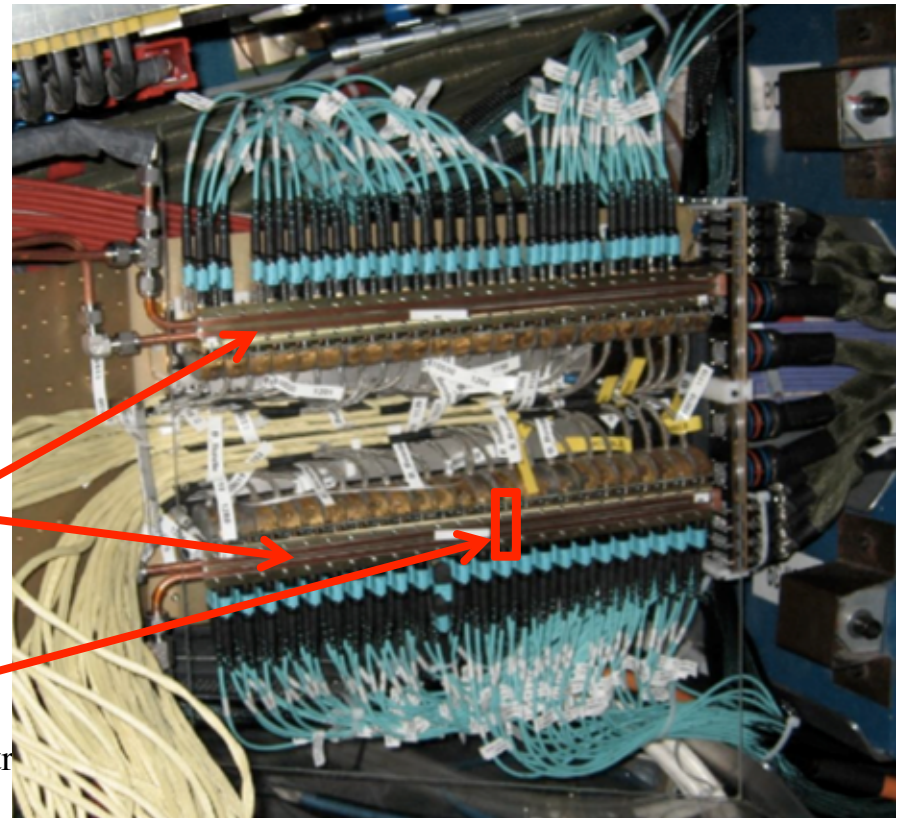 - Bit error bit: 1.3×10^{-15}
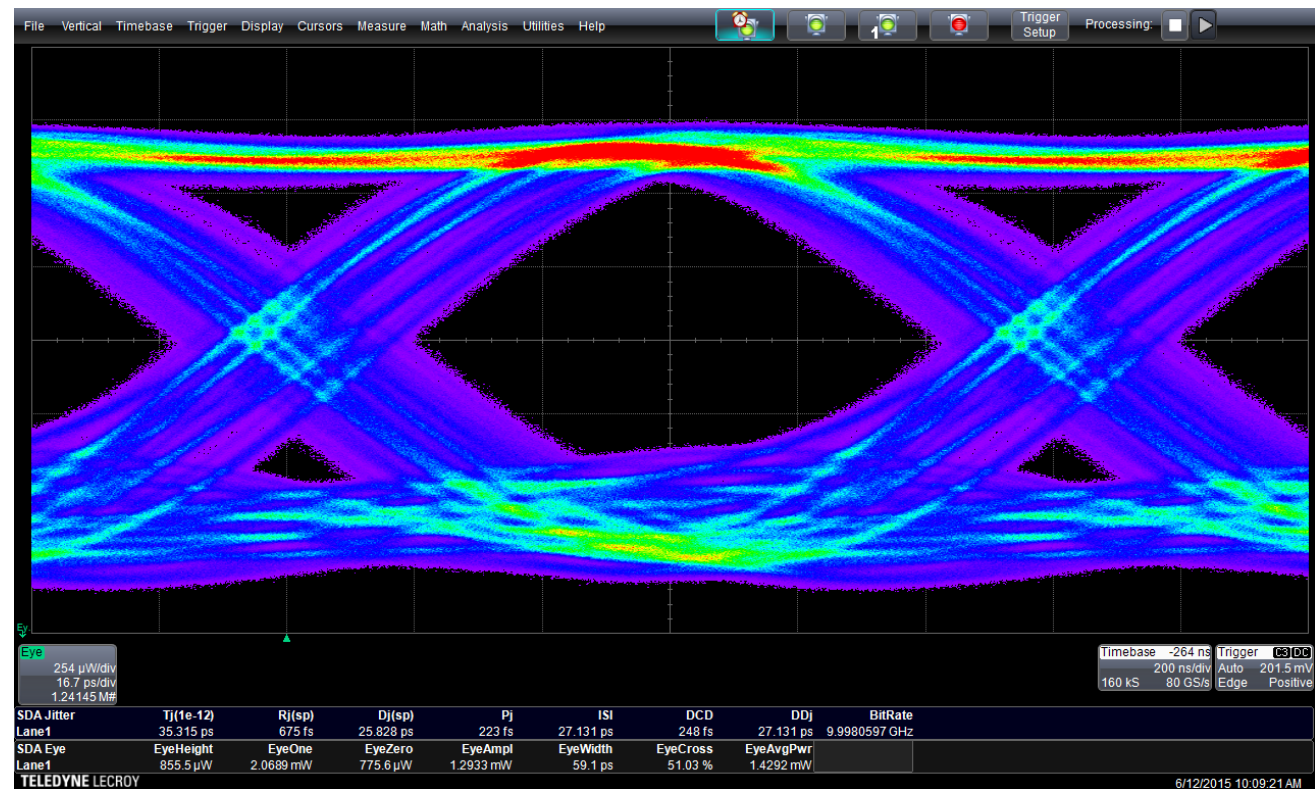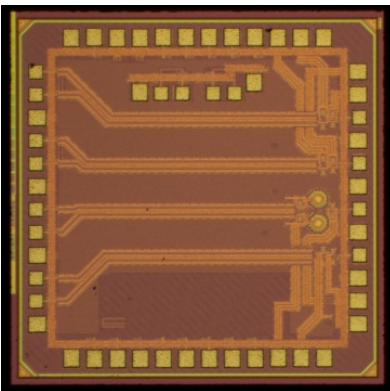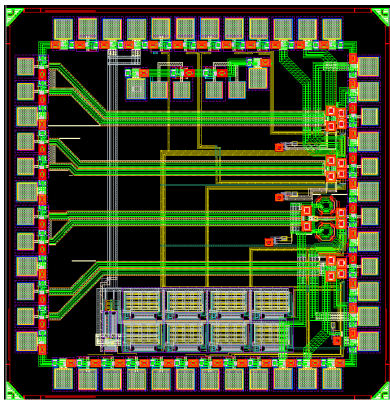
ITK-Pixel Opto-Box Concept

- ITK Opto-board allows for opto-box like mounting and cooling
- achieve similar density of fiber connectors
- all fiber cables exit vertically rather than from both sides
  - more compact packing/less messy
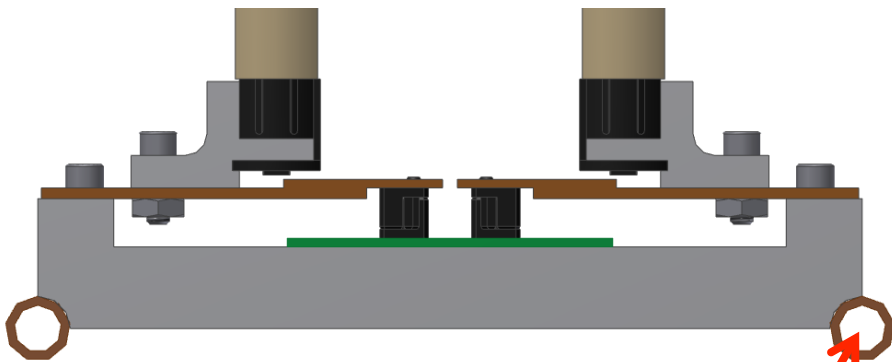
cooling rail

opto-board

K.K. Gan   ITK Pixel Electr

How About the Downlinks?

- It is more logical to also use 12-channel PIN arrays
  as in the 1st and 2nd generation opto-boards
- Highly desirable to have one downlink
  per module instead of per half stave
  - prevent the lost of half stave with a broken downlink
- One possibility is to take a stripped-down version of GBT
  and layout a 12-channel version

Summary

- Successfully designed and produced a prototype opto-board for ITK-Pixel including an ASIC and optical packaging to allow 5 Gb/s optical data transmission