Tracker Optical Link Upgrade R&D Plans and Status

K.K. Gan
The Ohio State University

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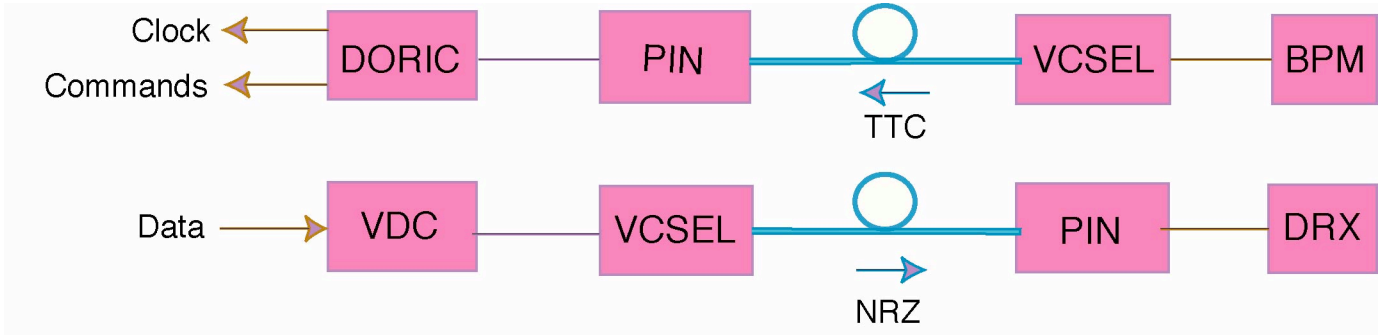
Outline

- Experience from Pixel opto-link
- R&D plans
- R&D results
- Summary

Inner Detector Optical Links

- SCT: ~ 12,000 links, including data transmission redundancy
- Pixel: ~ 4,000 links
  - based on SCT design
- both use driver/receiver of similar architecture:
  - VDC: VCSEL Driver Circuit
  - DORIC: Digital Optical Receiver Integrated Circuit



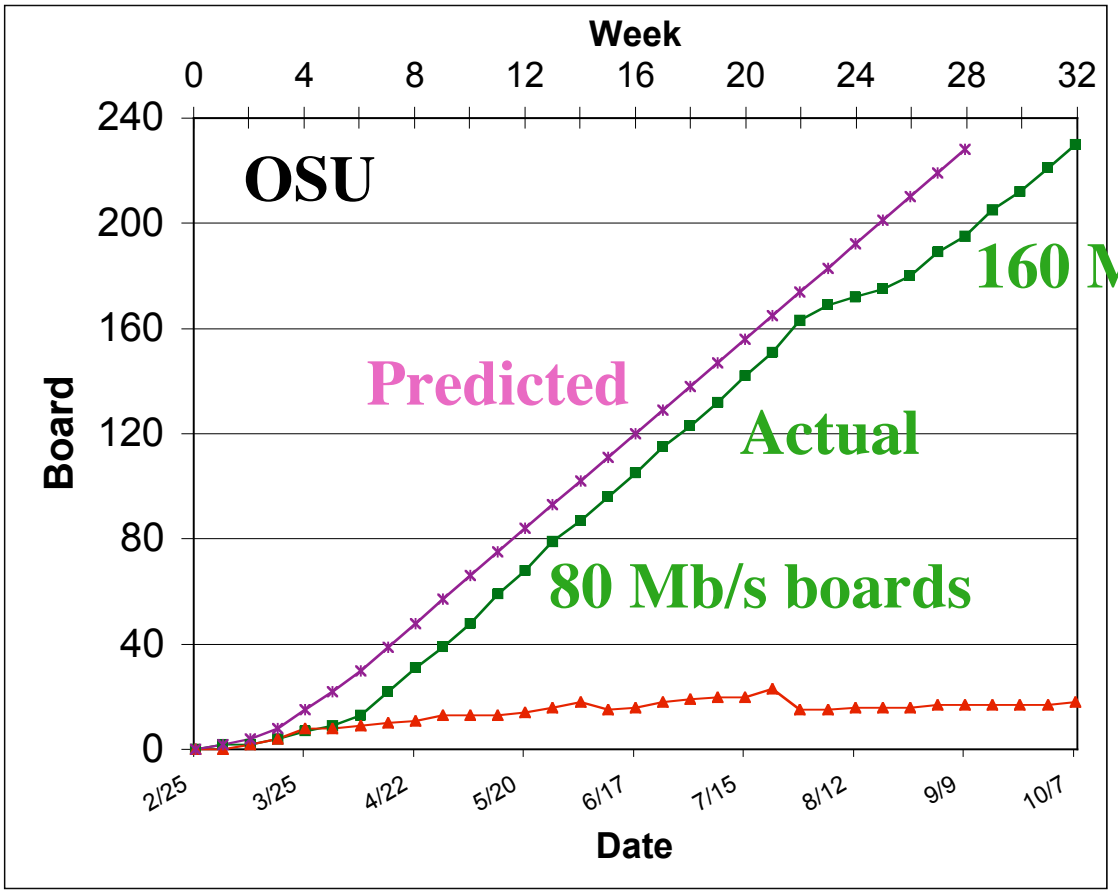
Inner Detector Optical Modules

- SCT harness:
  - speed: 40 Mb/s
  - single fiber (fragile)
  - short flex to reduce electromagnetic interference
  - many harness flavors
- Pixel opto-boards:
  - speed: 80 Mb/s using both clock rising/falling edges
    - B-layer uses two data links to transmit at 160 Mb/s
  - robust ribbonized fiber
  - ~ 1 meter of micro-twisted pairs
    - much reduced radiation level
    - decouple pixel module & opto-link production
      - ⇨ greatly simplify construction
      - ⇨ 2 BeO board flavors

Opto-board Production Experience

- few production problems

⇨ upgrade based on pixel link is widely viewed as logical choice



Bandwidth Requirements

- Inner Tracker Opto-Link Upgrade by Gan @ Genova:
  - pixel tracker:
    - 320 Mb/s: minimum
    - 640 Mb/s: more conservative
    - retain double links for innermost barrel
  - strip tracker:
    - multiple of 40 Mb/s per module
- can current pixel type0 cables & spliced fibers transmit data at 320 or 640 Mb/s?
  - ⇨ R&D

Radiation Hardness of VCSEL/PIN

- VCSEL/PIN from several vendors can operate at Gb/s
  - Can they survive SLHC dosage?
    - What is the PIN responsivity after irradiation?
    - What is the PIN SEU rate?
    - What is the VCSEL optical power after irradiation?
    - Can the VCSEL be annealed after irradiation?
      - What VCSEL current is needed for annealing?
    - US plans to characterize VCSEL/PIN from various vendors
      - design of test system in progress at Ohio State
    - SCT group has done neutron irradiations at Ljubljana
    - US/Germany plan to do irradiation at PS in 2006

Result on Neutron Irradiation of VCSEL/PIN

- Truelight VCSEL/PIN arrays were irradiated to various dosages with neutrons at Ljubljana reactor
  - PIN arrays not yet analyzed
  - ten 8-channel VCSEL arrays were irradiated:
    - arrays contained broken channels before irradiation
    - arrays were not biased during irradiation
    - after ~30 hours of annealing:
      - 8 arrays irradiated up to 5 x 10^{15} 1-MeV n_{eq}/cm^2
        - recover > 70% of optical power
      - 2 arrays irradiated to 10^{16} 1-MeV n_{eq}/cm^2
        - some channels lost all optical power

Result on 2 Arrays after 10^{16} 1-MeV n_{eq}/cm^2

- VCSEL array #10:
  - 7 working channels before irradiation
  - 1 channel drawing no current
  - 1 channel drawing current but produces no light
  - 2 channels: recover ~70% of optical power after annealing
  - 3 channels: same as above but intermittently
- VCSEL array #2:
  - 3 working channels before irradiation
  - 1 channel drawing no current
  - 1 channel drawing current but produces no light
  - 1 channel: recover ~15% of optical power after annealing

Implications of Neutron Irradiation Results

- VCSEL is not suitable for SLHC if results are confirmed
  - results might be different if intermediate annealing is possible
- ability to recover 70% of optical power on some channels and intermittently on other channels indicates that problems could be mechanical
- irradiation must be repeated with quality arrays
- US/Germany plan to use 24 GeV protons from PS at CERN next year with monitoring and annealing during irradiation

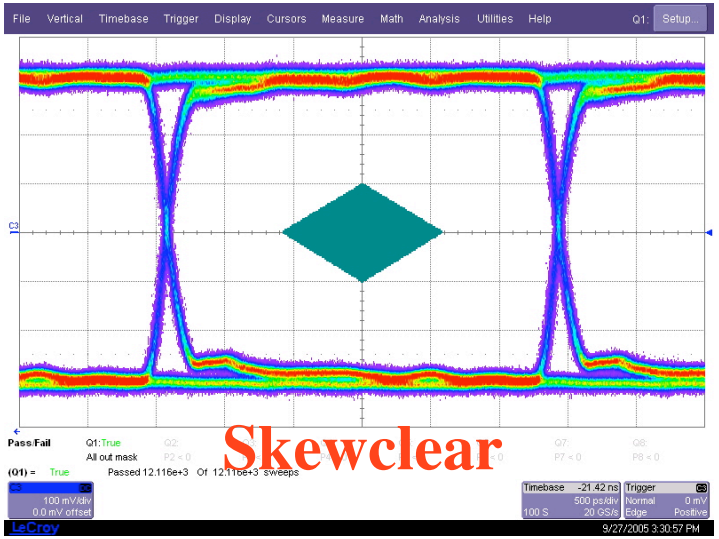
Bandwidth of Type0 Cables

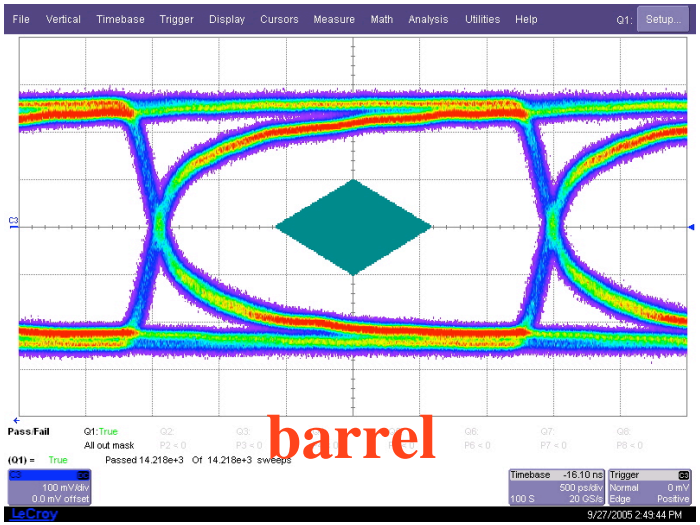
- Pixel modules transmit LVDS to/from opto-links with tiny wires
  - barrel:140 cm of 100 μm wires
  - disk: 60 cm of 60 μm wires

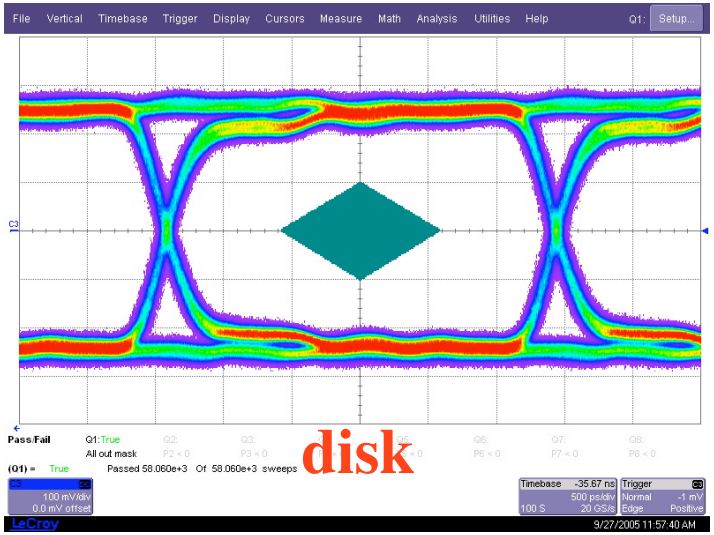
⇨ measure bandwidth and compare to Skewclear (150 cm/400 μm)

Time (ps) (20-80%)	Rise (ps)	Fall (ps)
Barrel	400	390
Disk	291	297
Skewclear	149	157
PCB Trace	128	130

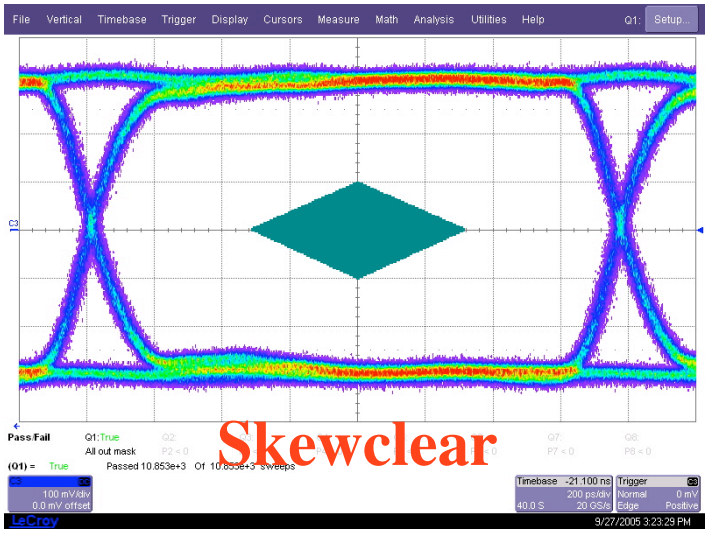
Eye Diagrams at 350 Mb/s

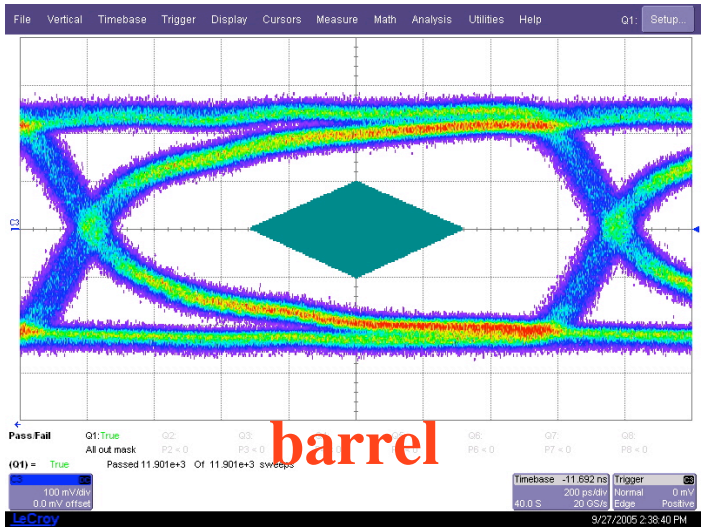


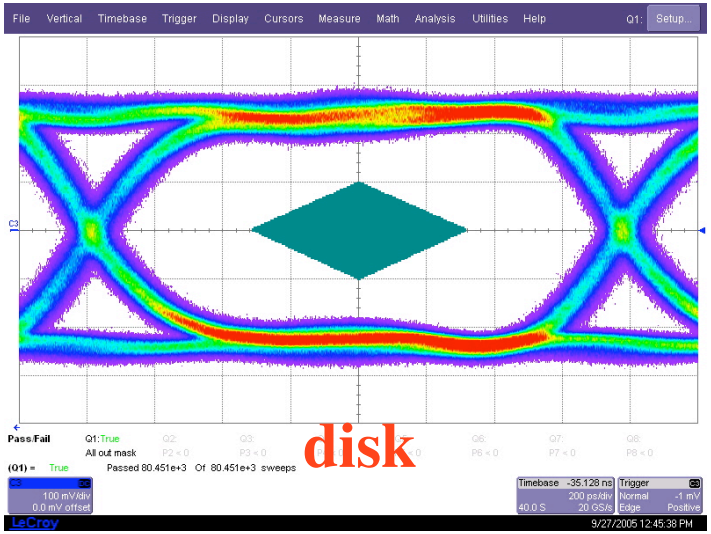




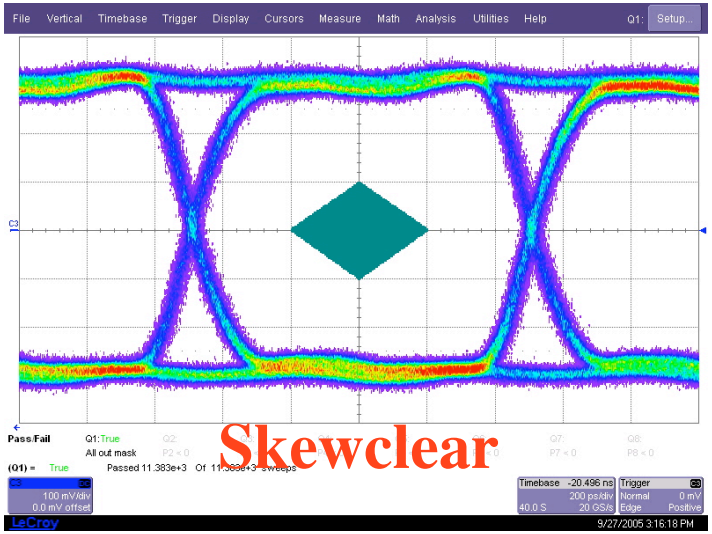
Eye Diagrams at 640 Mb/s

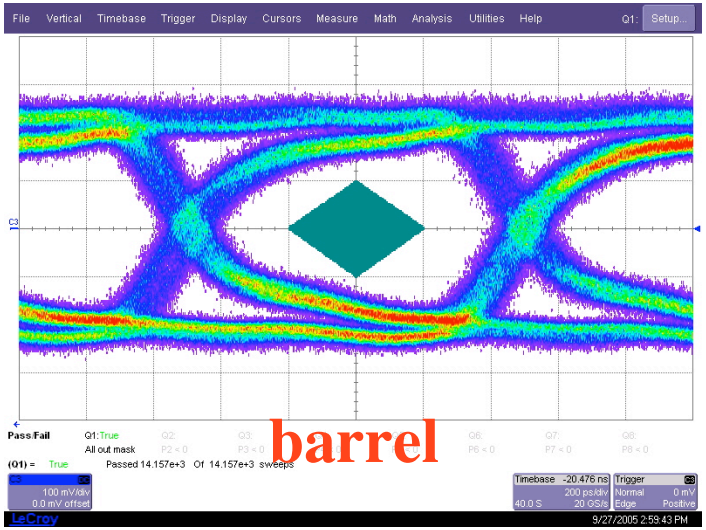


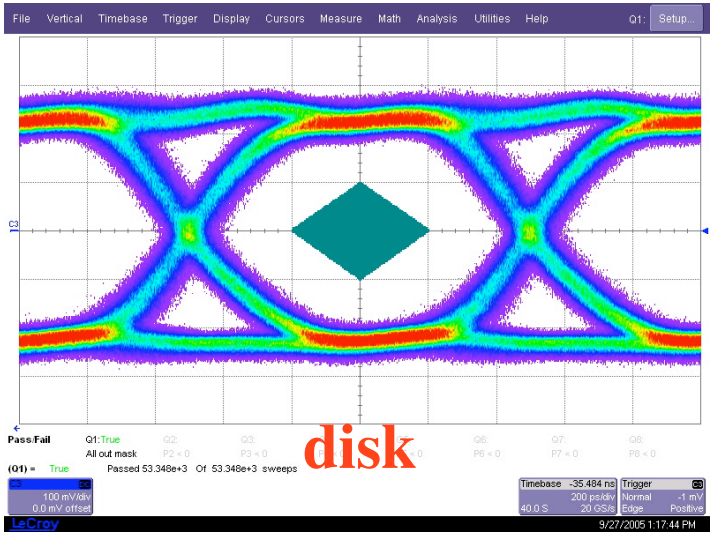




Eye Diagrams at 1 Gb/s

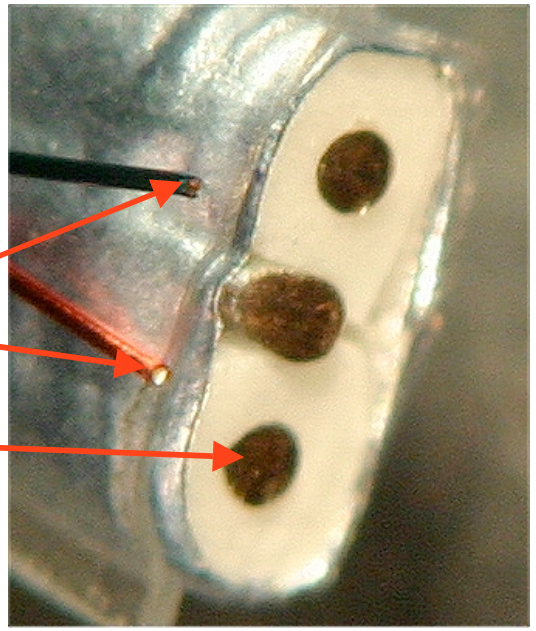






Summary on Cable Bandwidth

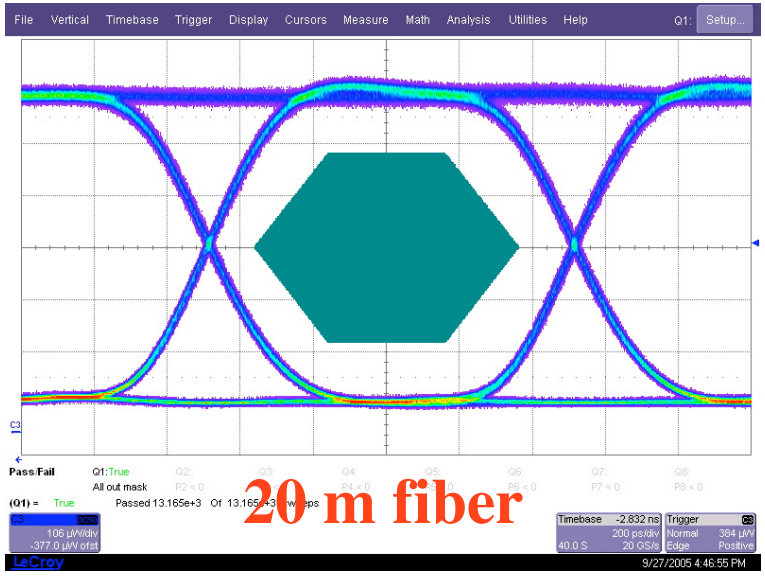
Thinking of using Skewclear?
A picture is worth a thousand words…



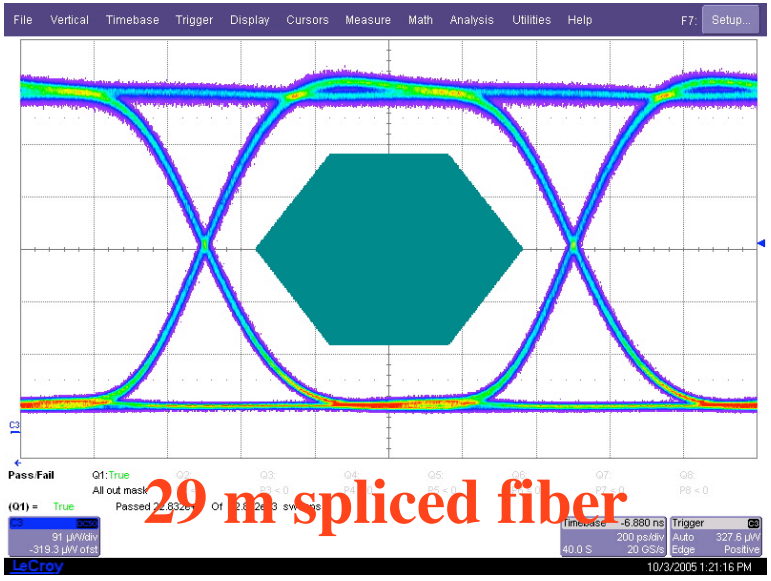
- transmission at 320 Mb/s may be adequate
- transmission at 640 Mb/s might be acceptable
- ordering custom micro-twisted cables
  to see if transmission will improve…

Bandwidth of Spliced Fibers

- Present Pixel: spliced several meters of SIMM with GRIN
  - SIMM: rad-hard pure silica core, low bandwidth
  - GRIN: rad-tolerant, medium bandwidth
- What is the bandwidth of spliced fibers?
  - Result: transmission at 1 Gb/s is quite adequate



1 Gb/s



Summary

- R&D in progress on current Pixel infrastructure
  - some Truelight VCSEL arrays die at 10^{16} 1-MeV n_{eq}/cm^2
    - problems might be related to quality of arrays
    - measurements will be repeated, including at PS
  - type0 cable may be adequate up to 640 Mb/s
  - spliced fibers sufficient for 1 Gb/s