Los Alamos NATIONAL LABORATORY

A New Way to Build Multi-Channel PDV Systems

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😐

Motivation

- Asked to add a lot of PDV channels at Point 88 (MPDV?).
- Also asked if there were cheaper and simpler systems we could just buy.
- What are the identified issues with our current systems?
  - Fragile (don’t move well)
  - Difficult to repair/maintain
  - Vibration sensitive fiber connections (FC)
  - Single fiber based, too many connectors!
  - VOA drift
  - Not fully remote controllable

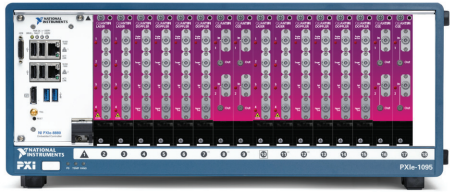
Motivation

- Rather than just copying what was done before, how can we:
  - Simplify the hardware and maintenance
    - Turn-key/off-the-shelf
  - Improve hardware robustness
  - Improve the signal-to-noise ratio (SNR)
    - Photoreceiver performance
    - Circulator directivity
  - Reduce analysis complexity/time

OK, Now What?

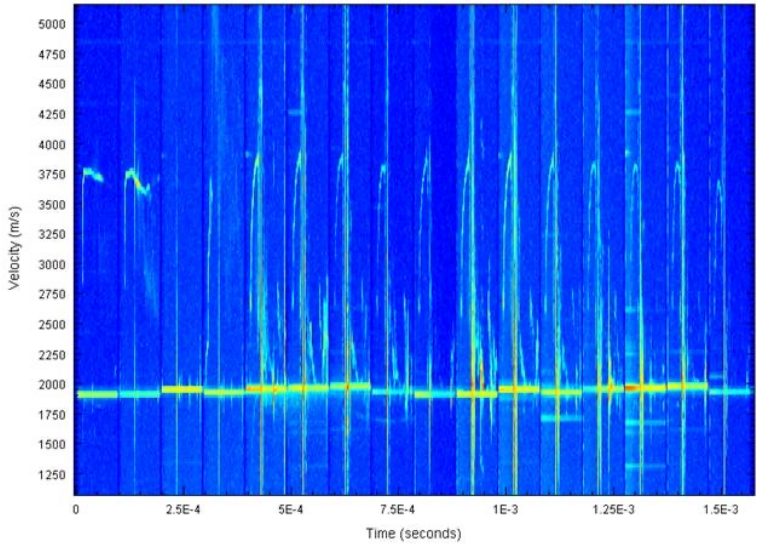
- Existing MPDV systems are large, expensive, difficult to maintain, and have limited performance.
- Commercial PDV systems are expensive, space inefficient, and not optimized for our needs.
- The goal was to design a new PDV architecture that was cheaper to build, provided better performance, and was easier to maintain.
- Oh, by the way, it needs to be fully remote controllable, mobile, and robust (shocks and vibration).

Dicon 4-ch PDV (1U)



Quantifi 8-ch PDV (4U)

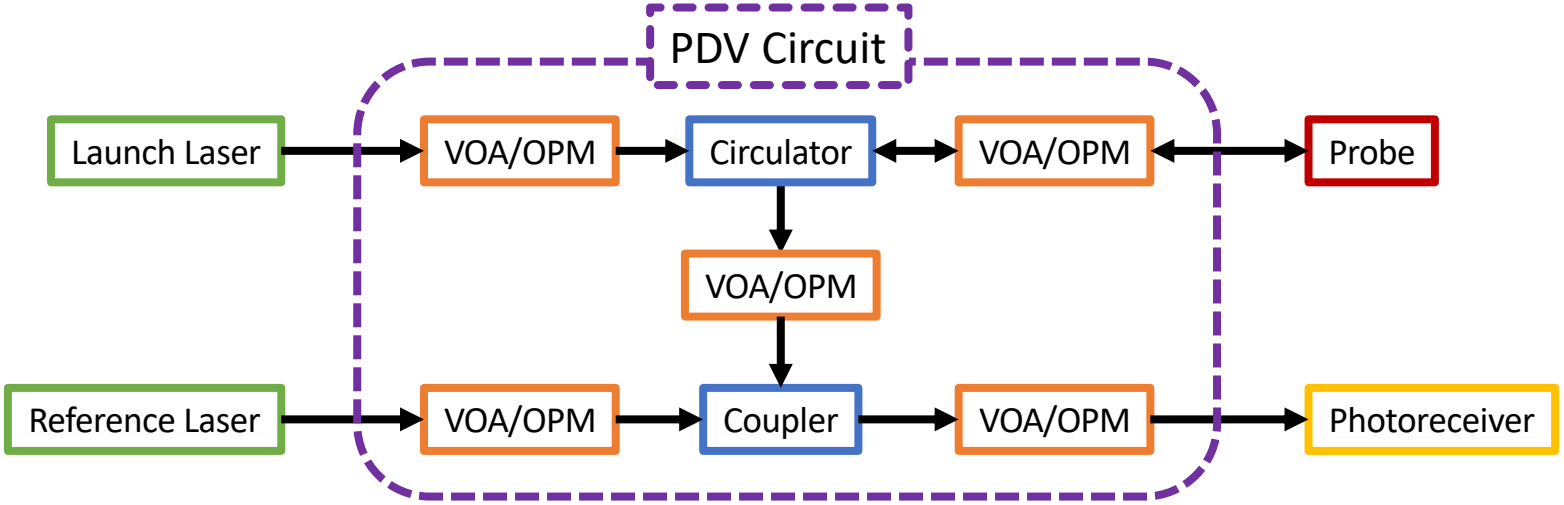
192 Channels @ DARHT



MPDV = multipoint photon Doppler velocimetry

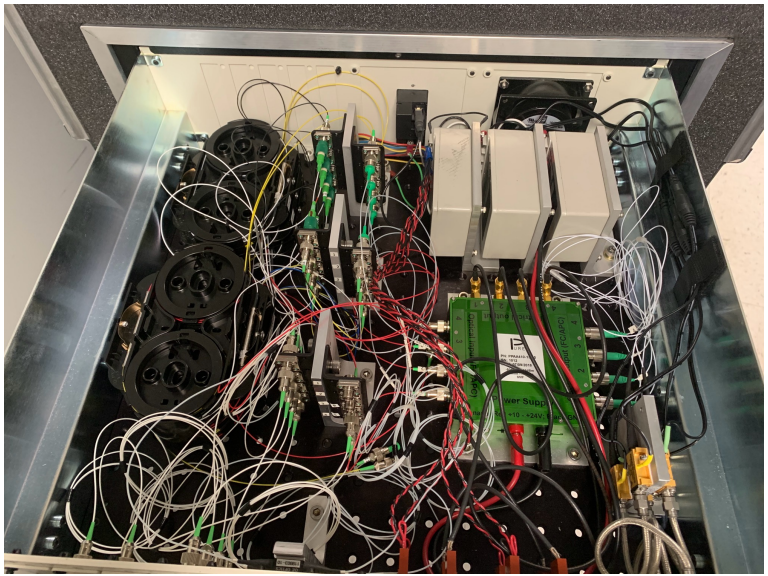
The old way of thinking.

- Make a bunch of single PDV circuits and cram them into a box.
- Scopes are expensive, so, let's use multiplexing. (Nobody needs more than 100 μs of data, anyway.)
- It's OK if we spend millions of dollars on a completely custom design that takes a PhD to run and a specialized crew to maintain.
- Cost of ownership? What does that mean?



VOA = variable optical attenuator
OPM = optical power meter

The results of the old way of thinking.

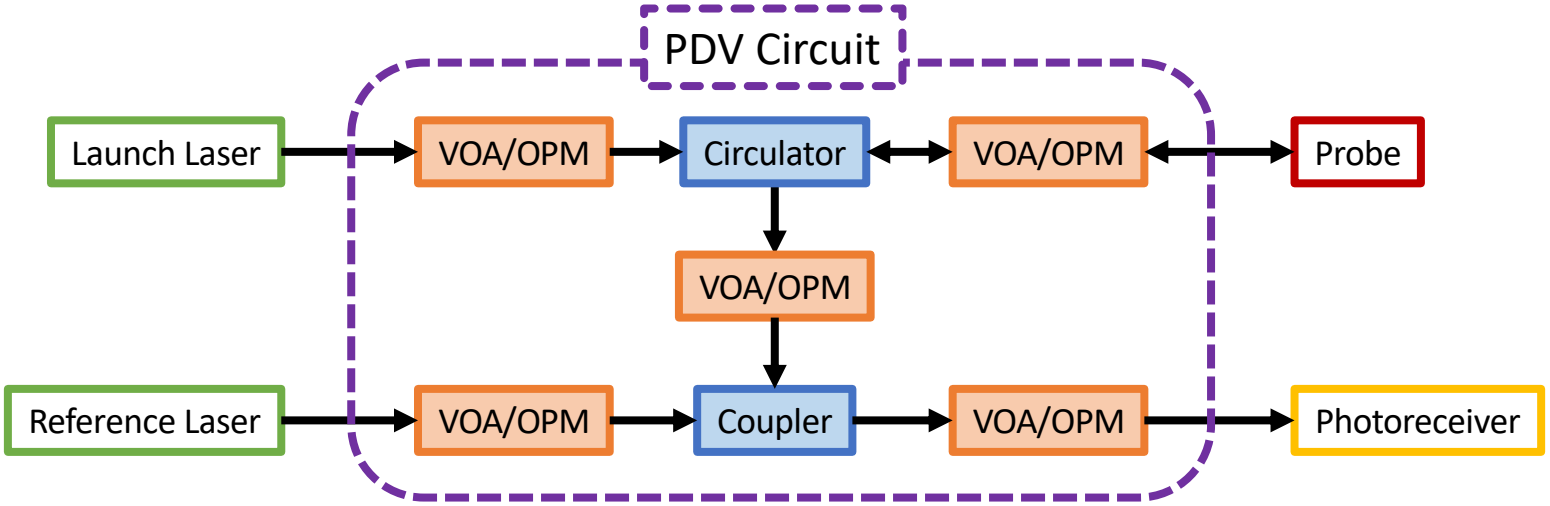


Legacy 4-ch PDV System

192 Channel MPDV @ DARHT

The new way of thinking.

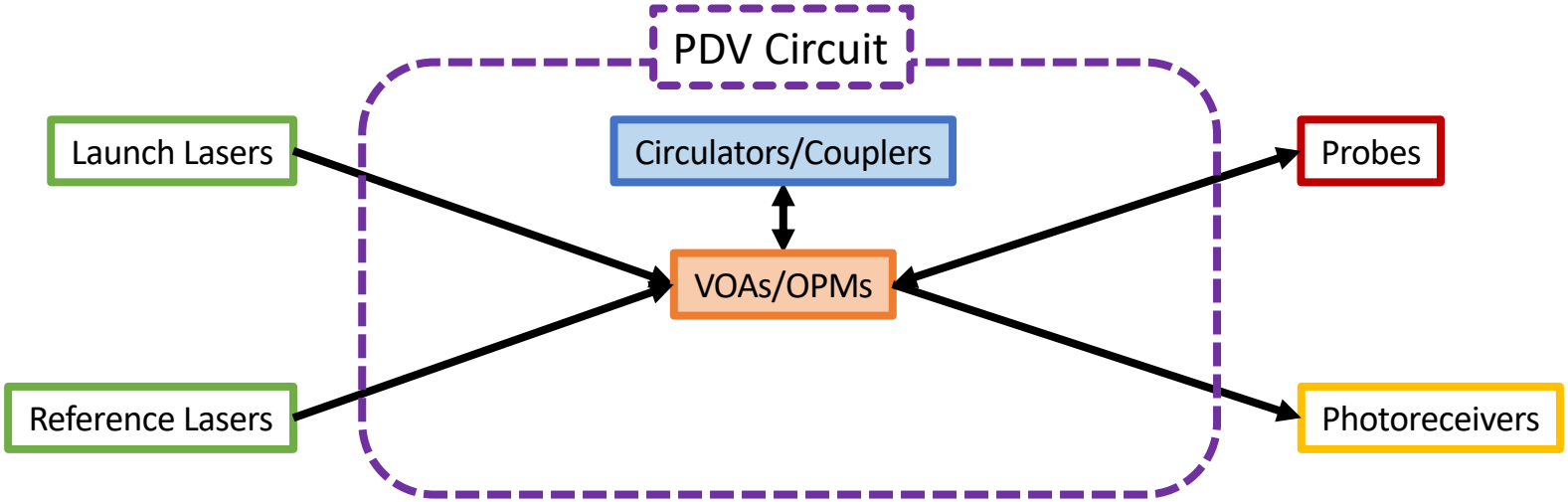
- What if we group like components and use high density multi-fiber connections?
- Can we utilize something to tie everything together?



MTP = multi-fiber termination push-on (US Conec)

The new way of thinking.

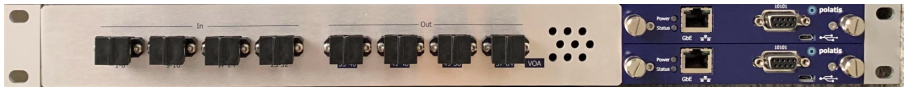
- Group like components and use high density multi-fiber connections.
- By the way, have you heard about a Polatis?



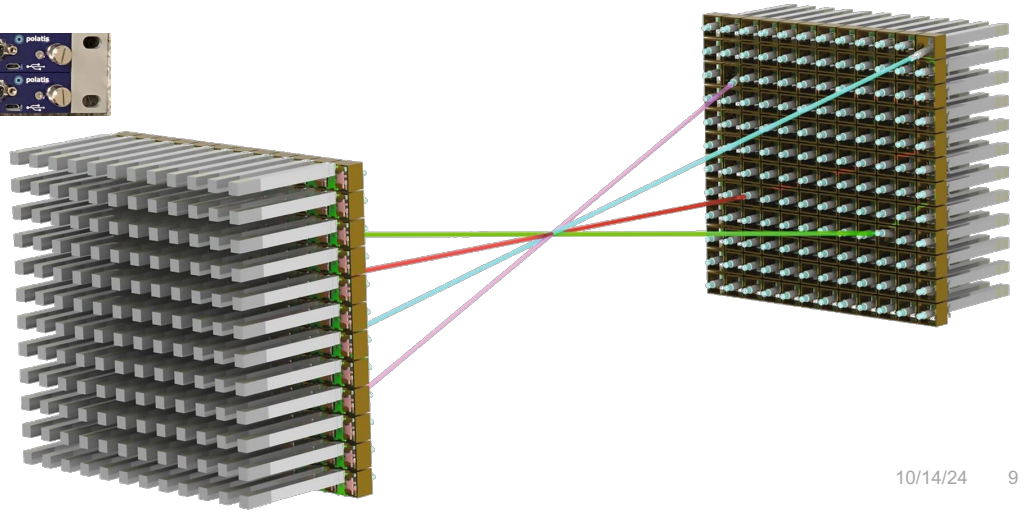
MTP = multi-fiber termination push-on (US Conec)

What is a Polatis?

- A Polatis is a NxN fiber matrix switch that uses movable probes to direct any input to any output.
  - Available up to 576x576 ports (rumors of a 768x768 ports unit).
- OPM's provide optical power monitoring and built-in VOA (absolute) functionality.
- Fully remote controllable via TCP/IP connection.
- Very robust (the Navy puts them on ships).

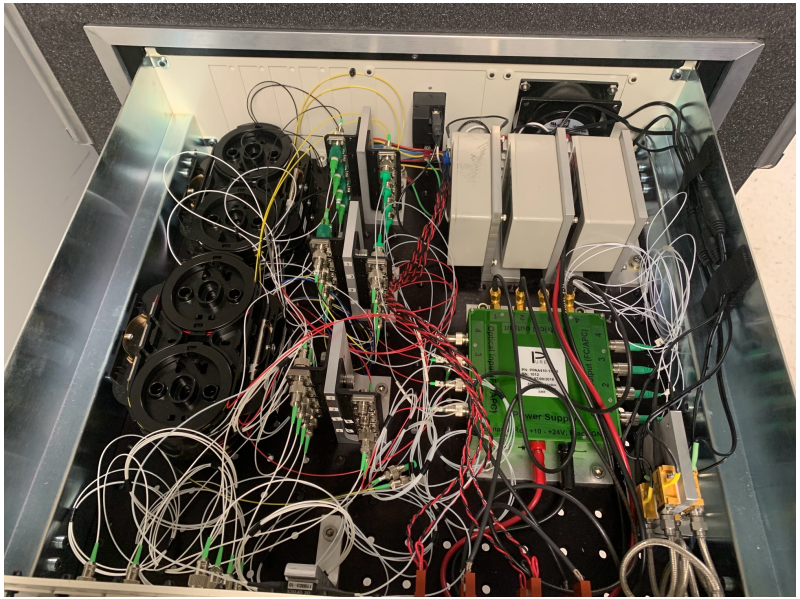


48x48 Polatis (1U)



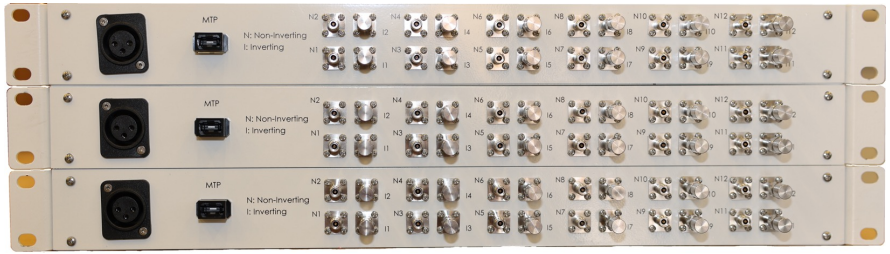
1U = 1.75"

Here's a visual.



4 channels = 3U (5.25")
36 channels = 27U (47.25")

192x192 channel Polatis is 4U tall

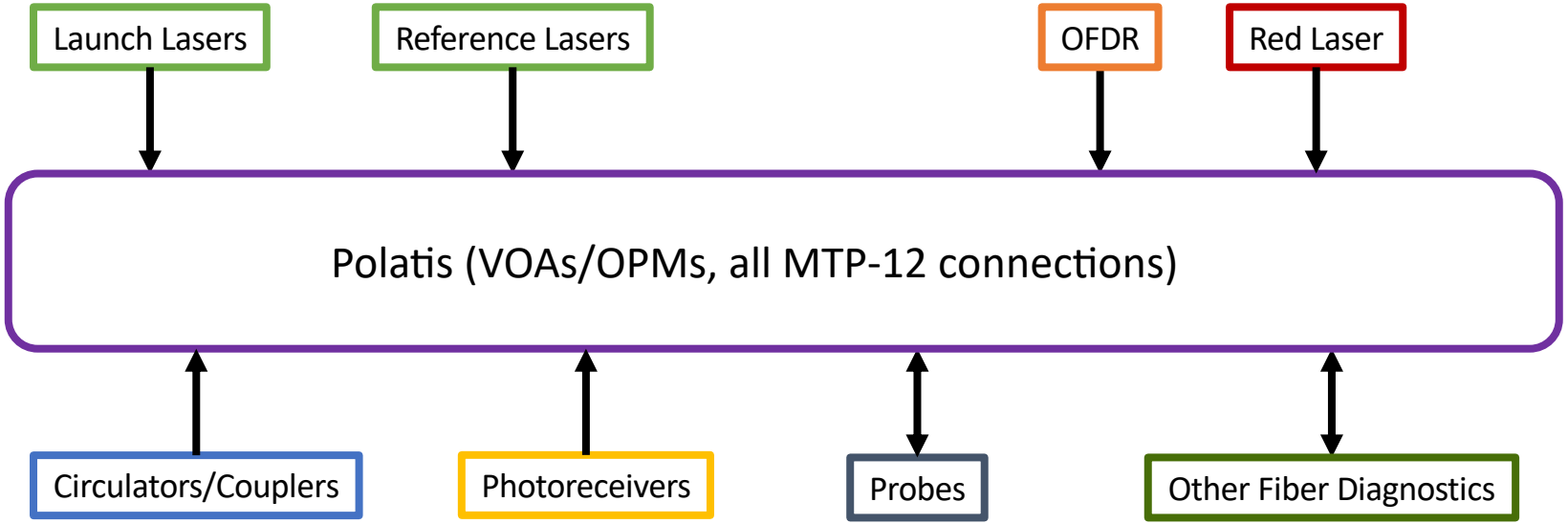


Photoreceivers are 3U tall

36 channels = 7U (12.25")

Here's another way to look at it.

- Every part of the PDV system can be connected or disconnected via switching in and out by the Polatis.
- OFDR or red laser can be switched in and out without breaking a fiber connection.



OFDR = optical frequency domain reflectometer (Luna, Apex)

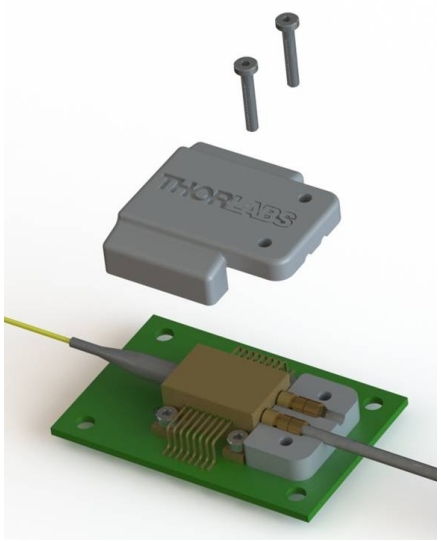
Putting it all together

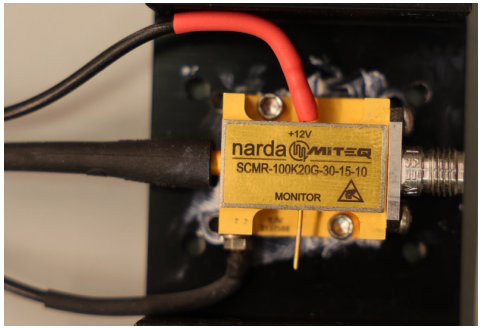
- Architecture scalable up to ~108 channels of PDV.
  - Latest design based on 192x192 Polatis provides 36 channels of PDV in 7U (minus scopes and lasers).
  - All connections MTP-12 (except seed lasers which are LC/APC)
- Outside vendors build all system components, all we do is mount in a rack and make connections.
  - Current max lead time for all components is 16-20 weeks.
- Integrated connections for OFDR, Red Laser, etc.

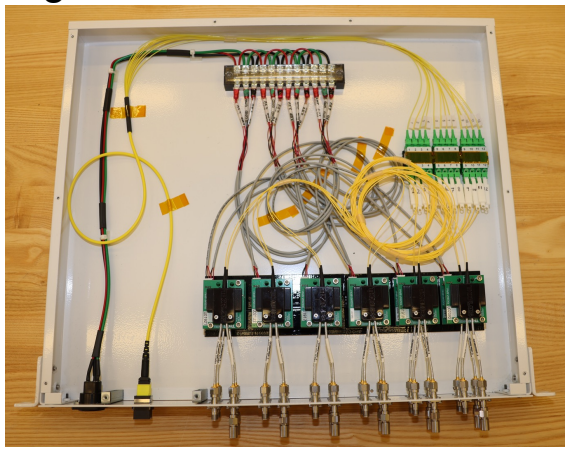
36 Channel PDV System in 28U Rack

Supporting Work

- Photoreceivers
  - Extensive study was performed to replace the Miteq SCMR-100K20G (0.1-20 GHz, ~2.8 W, 22 week lead time)
  - Settled on Thorlabs RX25AF (0.5-28 GHz, ~330 mW, in stock) which outperforms the Miteq (e.g. SNR)
  - Thorlabs built custom board and covers for us, RX25AF-SP1
  - Neptec connectorized to LC/APC, built housing for 12x photoreceivers, 1U rack space







Supporting Work

- Lasers
  - Initially used NKT Photonics Koheras BASIK X-15's in Acoustik chassis.
  - OEWaves built a dual locked laser system (launch and reference) with integrated amplitude (M-Z) modulators for modulation-based ranging (MBR) and 1x3 splitters
  - Fully remote controllable, 2U rack space
- Amplifiers
  - Initially used NKT Photonics Boostik amplifiers (15W/5W) with custom 1x32 splitters
  - Neptec built three dual fiber amplifiers (5W/2W) with integrated 1x12 splitters
  - Fully remote controllable, 2U rack space each (6U total for 36 channels)
- Couplers/Circulators
  - Initially Neptec built 8x coupler/circulators with MTP-8x modules.
  - Neptec built coupler/circulator assembly with MTP-12x to mount inside Polatis (eliminated 6x MTP jumpers per 12 PDV channels)

Cost of Ownership

- Total cost of ownership includes: **initial hardware costs + fielding costs + maintenance costs**
- **Initial hardware cost**
  - PDV only, $715k ($19.9k/ch)
  - MBR, $81k ($2.2k/ch)
  - Scopes, $1.18M (LPD64, 8 GHz, 1Gpt/ch)
  - PDV+MBR+Scopes, $1.98M ($54.9k/ch)
- **Fielding costs**
  - Fielding and maintenance experience: Technician/technologist level
  - Reduced complexity
  - Significantly reduced number of fiber connections/connectors
  - Mobile, reduced footprint, fully remote controllable
  - Simple to breakdown/setup for moving
  - Analysis experience: varies but reduced (increased SNR, no multiplexing)
- **Maintenance costs**
  - All components are turnkey and easily serviced/replaceable
  - Reduced number of fiber connections, no exposed fiber (armored), and no mating cycles for OFDR measurements or red laser

Summary

- All components are now turn-key from vendors.
- A technologist or technician can build and field it.
- Better data quality and not time window limited.
- OFDR scans/health checks without disconnecting fibers.
- Easily scaled up or down.
- Mobile and fully remote controllable.
- Can easily include:
  - Modulation based ranging (MBR)
  - Polarization control
  - Even multiplexing (although, why would you?)

Conclusion