CryoElectronics testing at Fermilab

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Cryo-electronics motivations and efforts

from within the Detector Electronics group at Fermilab

- **Big Caveat**: There are other efforts with cold electronics for DUNE horizontal-drift and the short-baseline neutrino program that I'm not aware of.
- Our main focus for Cryo-electronics is the DUNE Vertical Drift Photon Detector System
  - Focusing on Liquid Argon/Nitrogen temperatures: interested in solutions that work at Liquid Helium temperatures too.
  - The Photon Detectors will be at 300KV above the detector ground, so all power and communications is over fiberoptic cable.
  - Testing Cryogenic operation of:
    - FPGA
    - Multi-gigabit fiber transmitters
    - ADC
    - Fiberoptic JTAG and SPI (must support DC-few Mbps)
    - Power-over-Fiber

FPGAs

Primarily me, Jonathan Eisch

- Efforts surround the CryoCAPTAN
  - The internal configuration clock has been used successfully for chipscope

```
STARTUPE2_inst : STARTUPE2
generic map (
   PROG_USR => "FALSE",  -- Activate program event security feature. Requires encrypted bitstreams.
   SIM_CCLK_FREQ => 0.0  -- Set the Configuration Clock Frequency(ns) for simulation.
)
port map (
   CFGCLK => CFGCLK,         -- 1-bit output: Configuration main clock output
   CFGMCLK => CFGMCLK,       -- 1-bit output: Configuration internal oscillator clock output
```

  - Tested the transceiver channels in the Artix-7 and they work in the cold.
  - Currently testing some of the oscillators mentioned in: https://ieeexplore.ieee.org/document/8597484

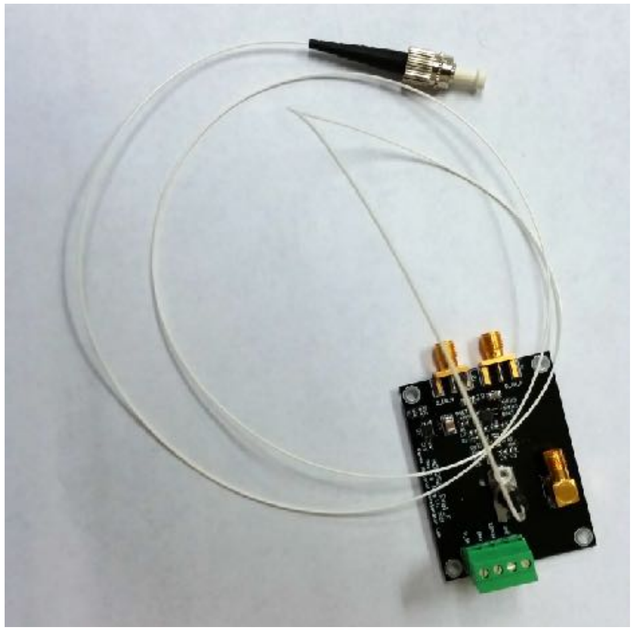
TABLE II: Obtained specifications for the 5 functional crystal devices. The two best performing devices are highlighted. Phase noise (PN) is reported at 100 Hz, 10 kHz and 1 MHz offsets from the main carrier (either 50 or 100 MHz).

	Aker S53305-50.000-X		Epson SG5032CAN		Quantek QX533A50.0B15M		IQD LFSPXO009438		TXC 7W-100.0MBB-T	
Temperature	4 K	300 K	4 K	300 K	4 K	300 K	4 K	300 K	4 K	300 K
Frequency [MHz]	49.940	49.999	49.944	50.000	49.948	49.999	99.882	99.998	99.884	99.999
Phase $\text{jitter}_{\text{RMS}}$ [ps]	14.06	0.52	2.52	0.32	0.91	0.32	2.25	0.24	0.62	0.35
Power [mW]	20.6	18.3	15.4	14.5	13.8	11.0	24.0	28.0	21.3	22.5
Carrier [mV]	351	515	617	591	562	527	638	617	524	620
PN @ 100 Hz [dBc/Hz]	-89	-114	-82	-119	-90	-113	-81	-110	-99	-104
PN @ 10 kHz [dBc/Hz]	-107	-136	-133	-142	-140	-140	-113	-136	-122	-131
PN @ 1 MHz [dBc/Hz]	-117	-147	-146	-153	-147	-152	-135	-146	-142	-143

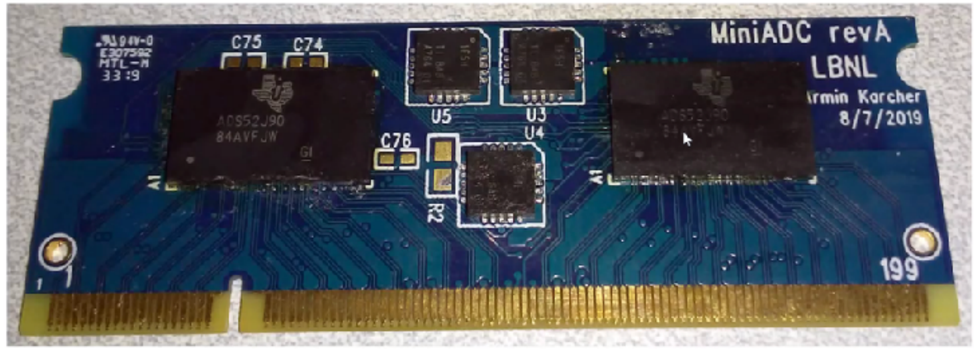
Multi-gigabit Fiber Transmitters

Primary Alan Prosser

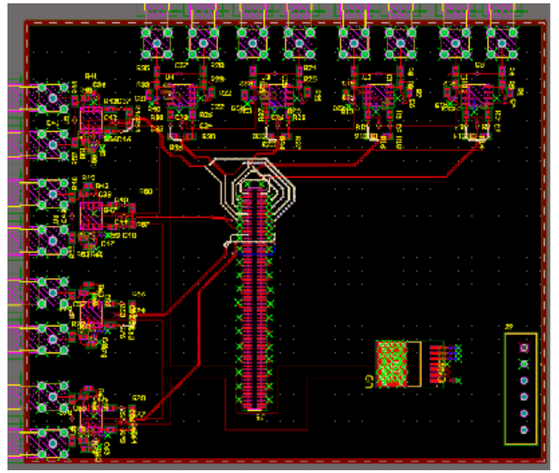
- Tested various commercial SFP(+) modules
  - In general, the problem is the driver chip, which may work if it is powered up warm and then cooled, but not if they are powered up in the cold.
- Currently testing configuration-free laser driver to try to make a custom working solution.



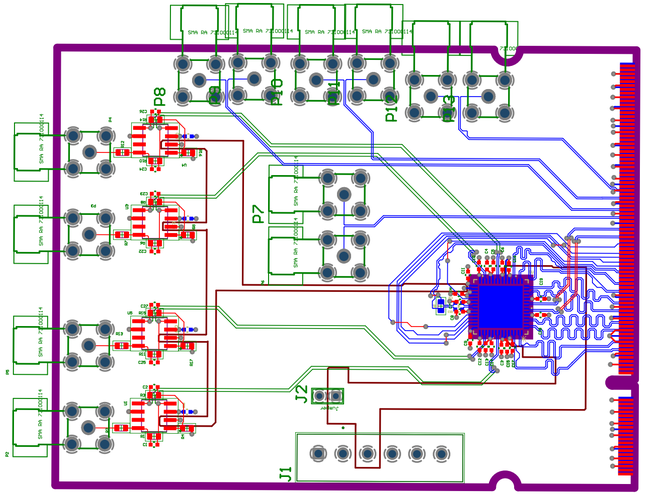
ADCs



- We have a MiniADC in hand.
  - We've (mostly) built an analog front-end board, but have been waiting over a month for the Samtec connector to plug into the CryoCAPTAN.
  - Samtec still shows shipping in the 1st week of December

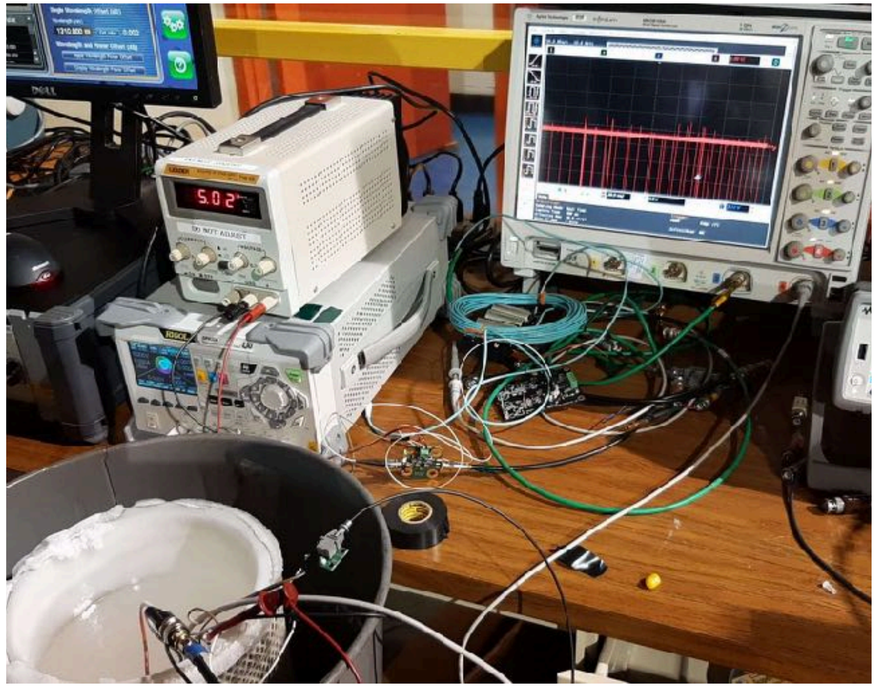


- We will be adapting the analog front end board for the miniADC to input to the Artix-7 X-ADC.
- We are also testing other ADCs like the TI ADC3444
  - Quad channel, 14-bit, 125MSPS
  - (Currently low-priority)



Low-speed Fiberoptic communications

- Needed for DUNE Vertical Drift operation
- All transmitters we've tested have worked just fine (basically a LED in a package)
- We have purchased ~10 devices are are currently testing them.
  - Devices with TTL-compatible output are easiest to use, but the output circuits have been failing in the cold for the ones we've tested.
  - Power over Fiber receivers have been shown to work but are overkill for this application.



Testing a receiver about an hour ago