The cryogenic performances of specific optical and electrical components for a liquid argon time projection chamber

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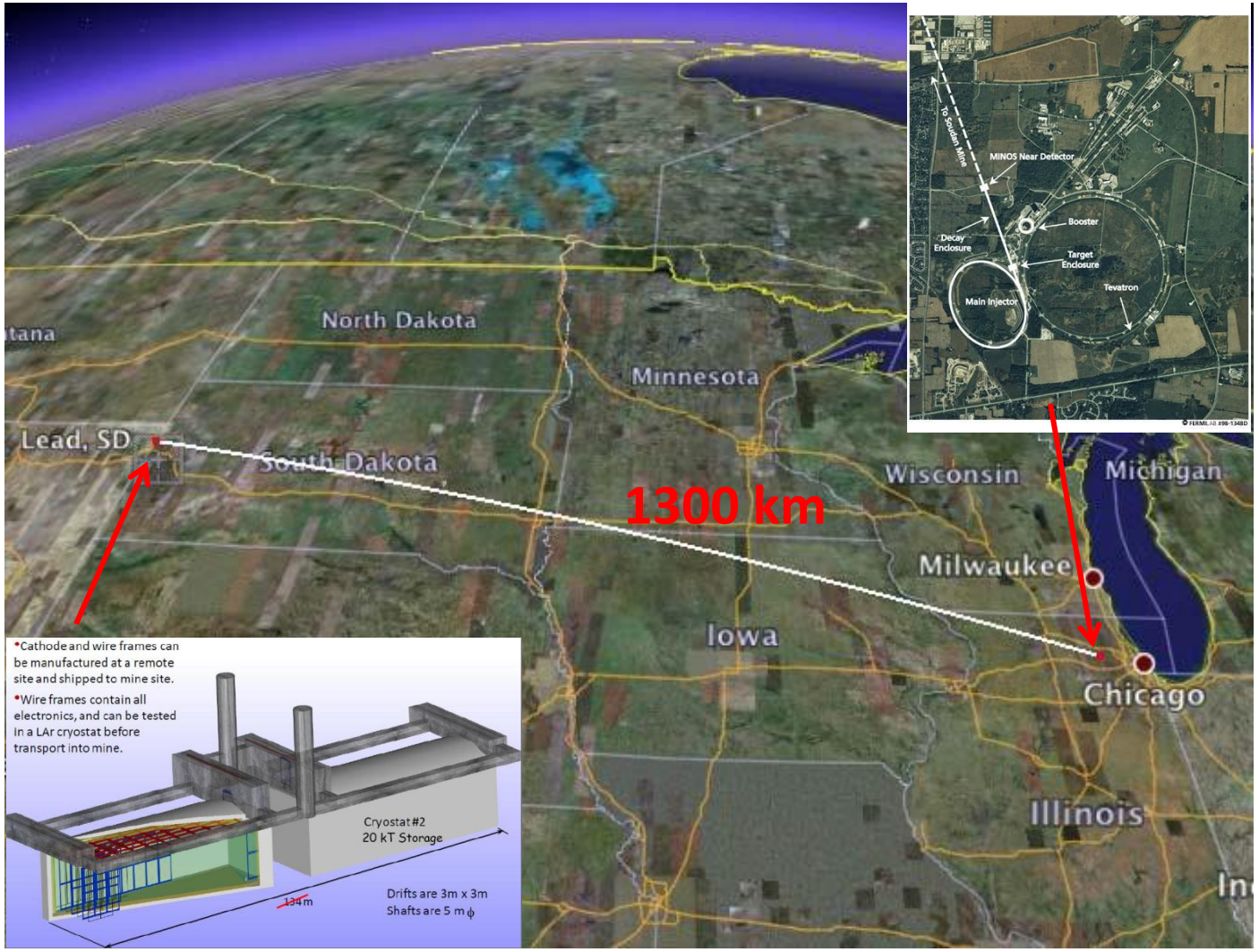
Outline

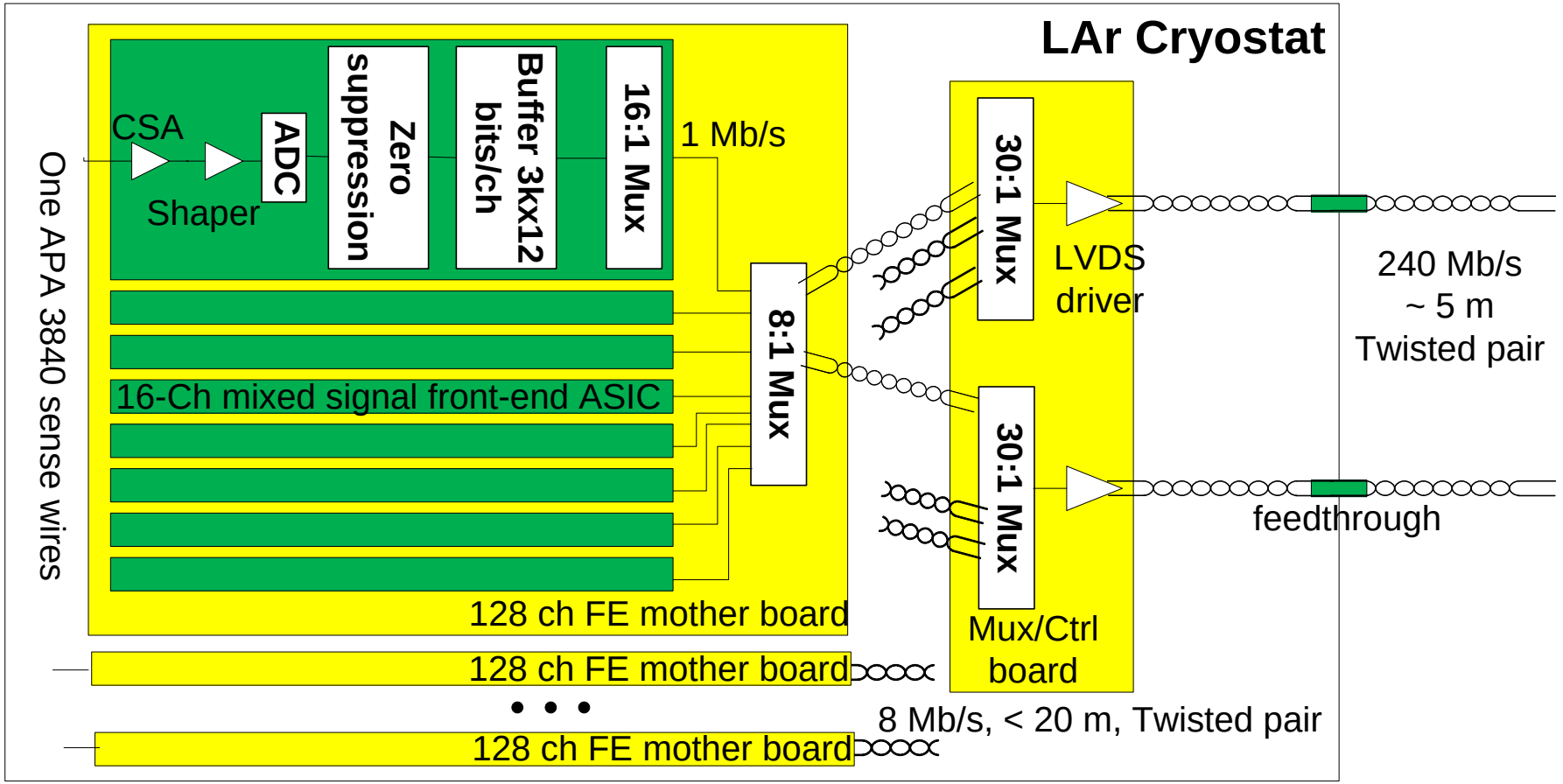
- Introduction of LBNE and LArTPC
- Cryogenic performance of electrical data links
- Cryogenic performance of optical data links
- Cryogenic performance of FPGAs
- Cryogenic performance of passive components
- Conclusion

Long-Baseline Neutron Experiment & Liquid Argon Time Projection Chamber



Front-end Electronics – LArTPC at 800' underground

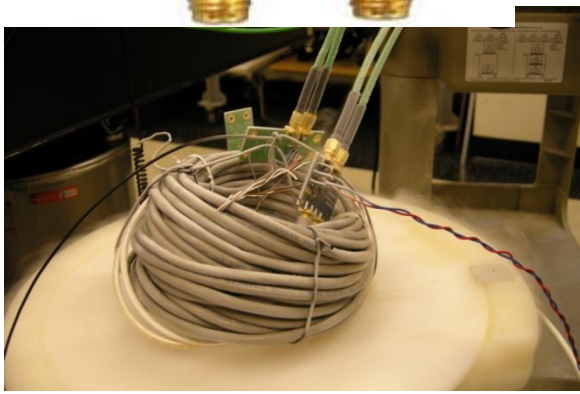
17:40pm, Craig thorn, "Cold electronics development for the LBNE LArTPC", Room: Superior A

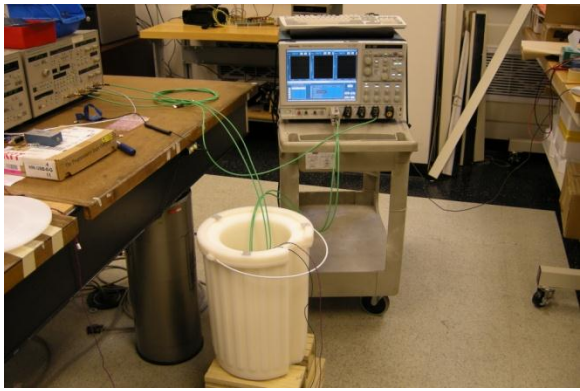


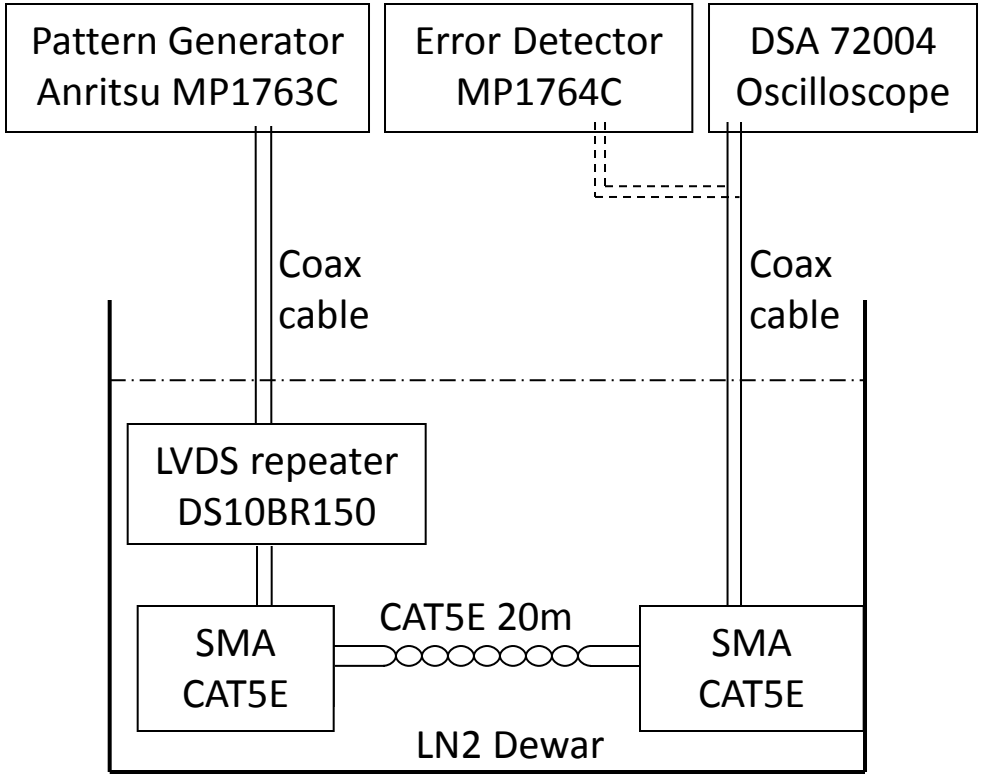
One Anode Plane Assembly (APA) is shown

Electrical Links – Test setup

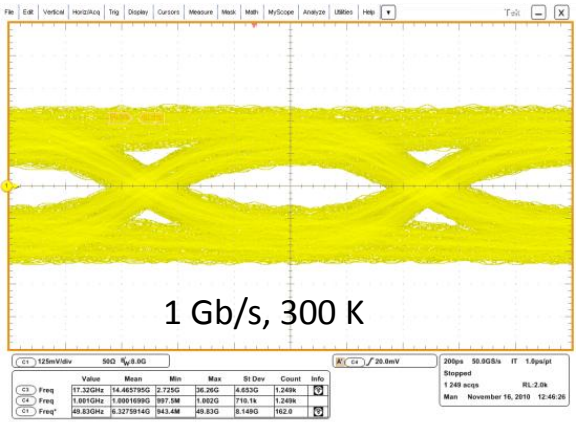
Motivation: **how fast** can an LVDS signal be transmitted over **how long** twisted pair cable at cryogenic temperature?

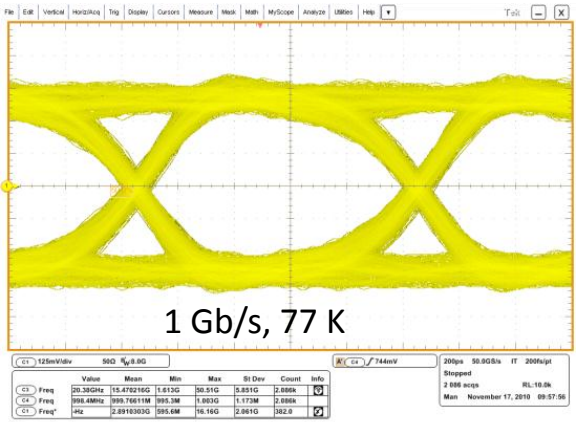






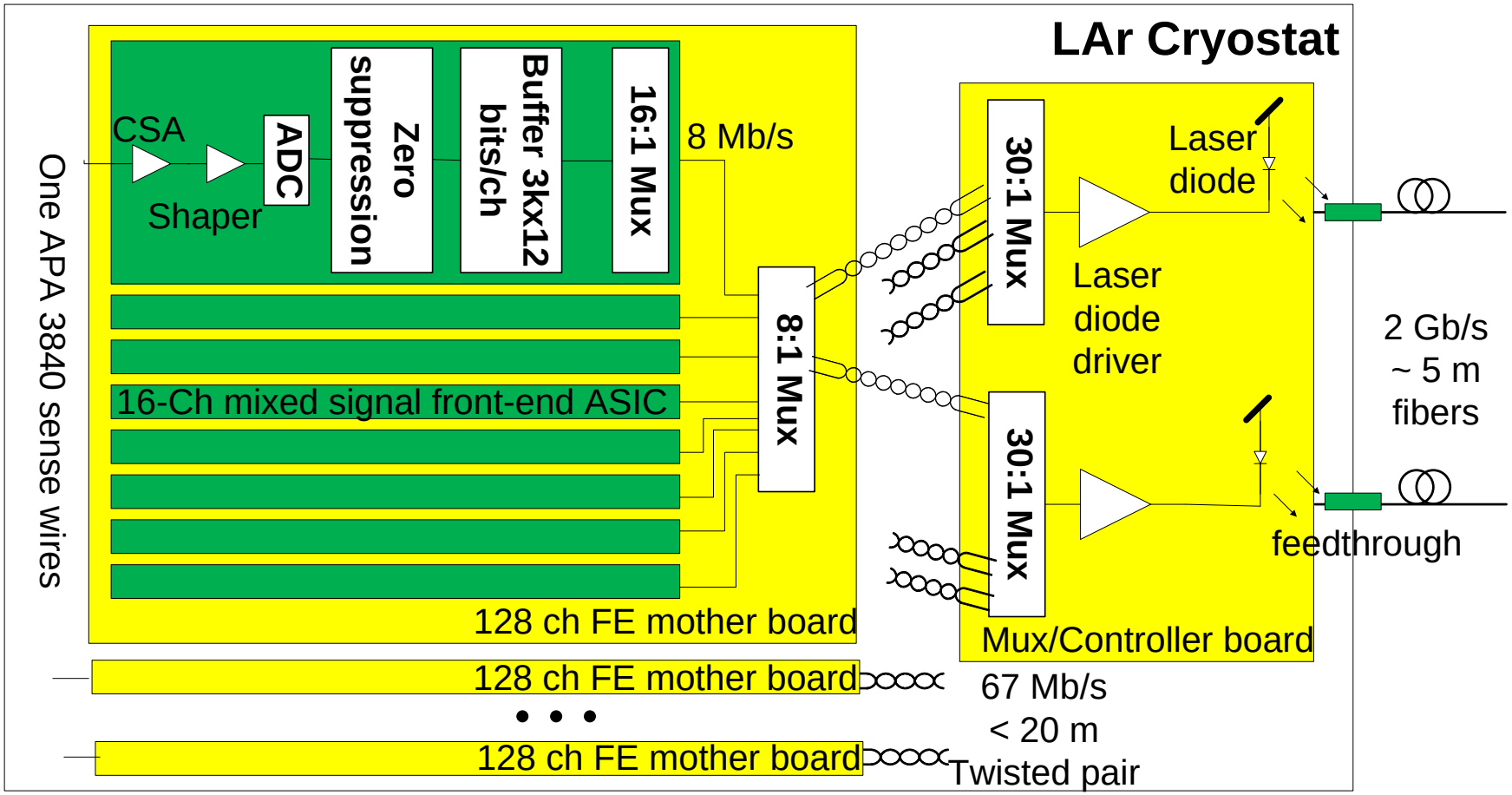
Electrical Links - Results





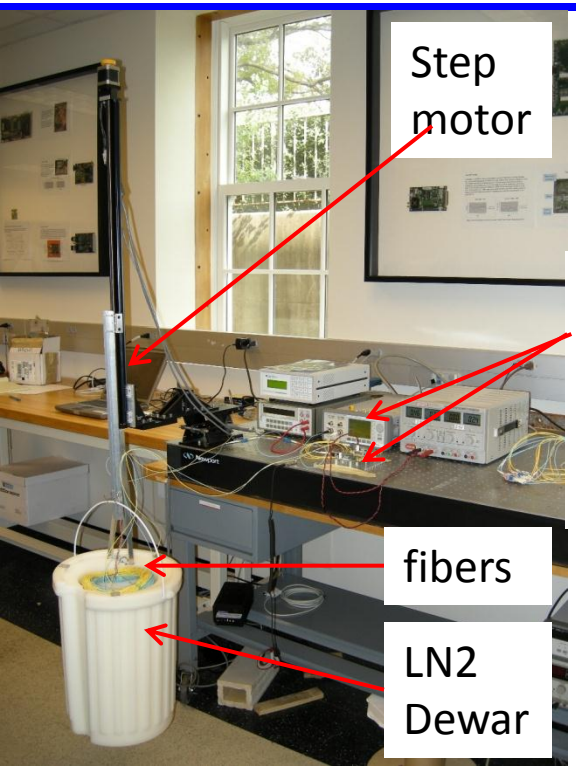
- The electrical link works at room temperature (300 K). The bit error rates (BER) < 8.2E-14 at 1 Gb/s (no error in 3 hours 23 minutes)
- The eye diagrams at 77 K have wider eye opening than those at 300 K. At 1 Gb/s, the bit error rate (BER) is < 3.9E-13 (no error in 42 minutes).

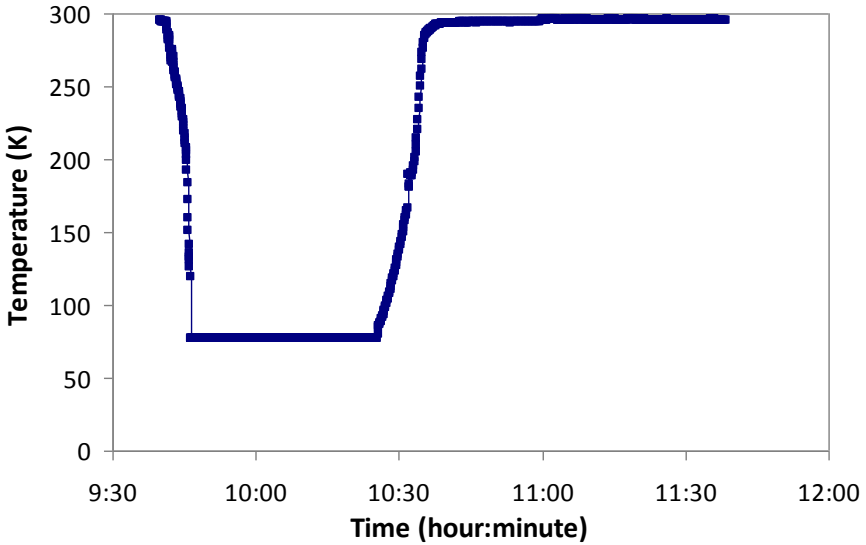
FE Electronics – LArTPC on the surface

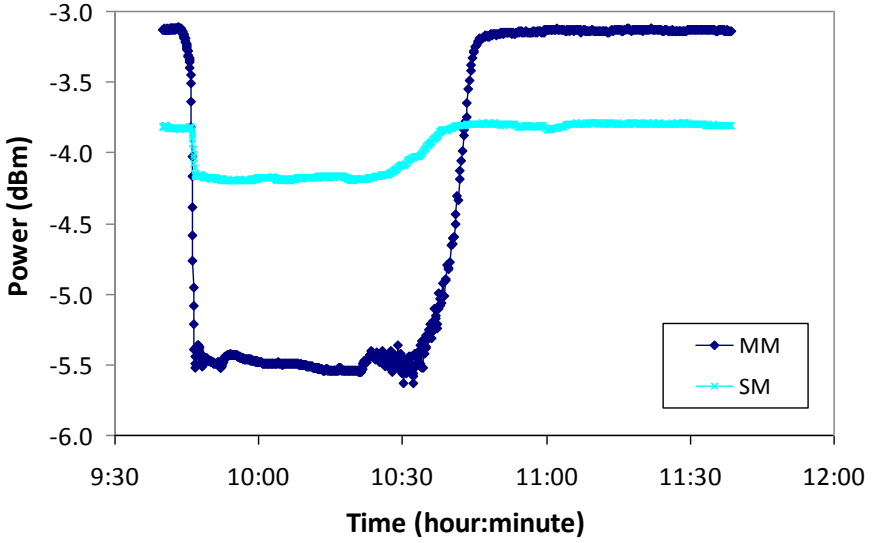


One Anode Plane Assembly (APA) is shown

Optical Links – Optical fibers







Results:

Fiber insertion loss increases from RT to 77 K:

MM: 0.034 ± 0.015 dB/m

SM: 0.005 ± 0.002 dB/m

Compare: the power budget (7.3 dB for MM and 9.4 dB for SM in the 10 Gb/s Ethernet standard).

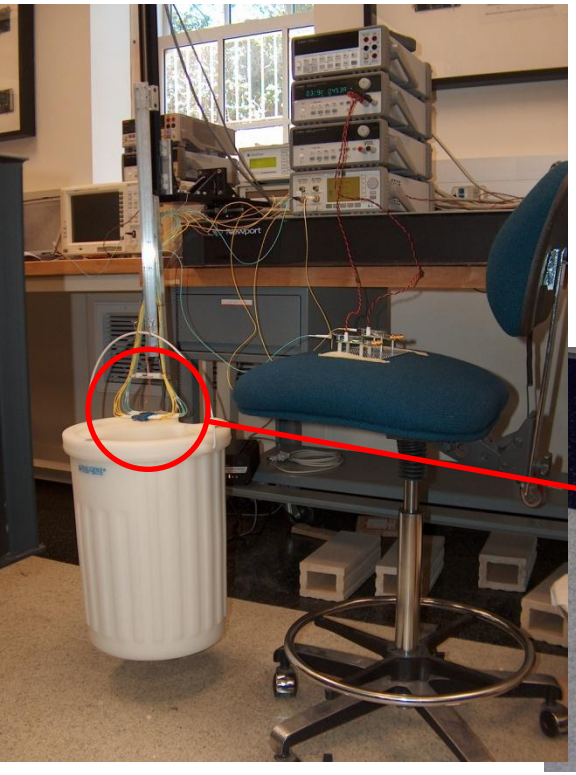
Optical Links – Optical connectors

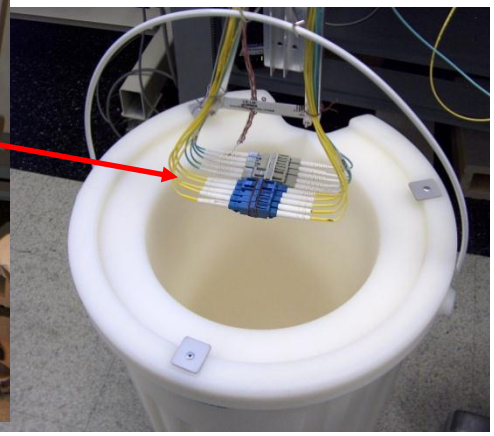
Results:

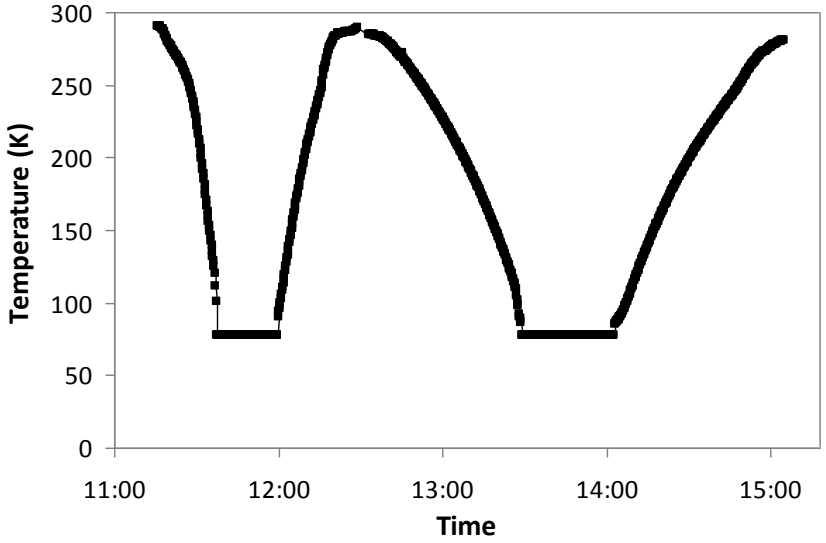
Insertion loss change from RT to 77 K:

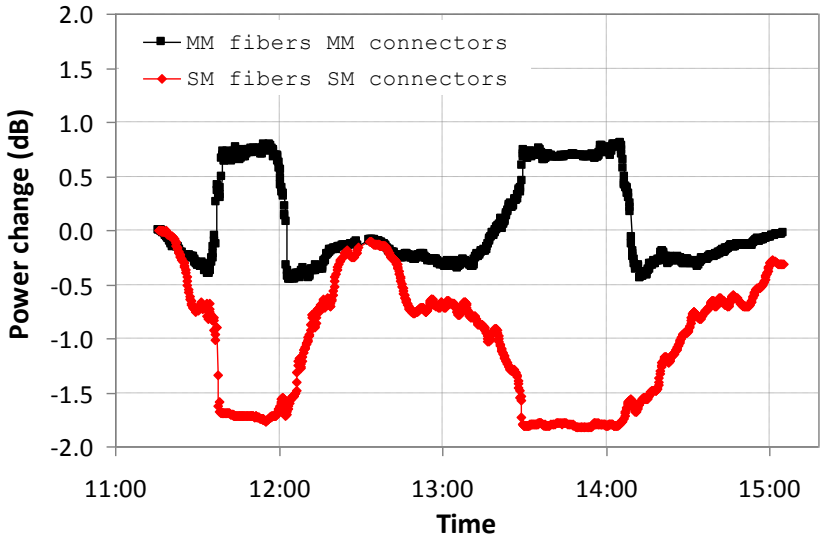
MM: 0.139 ± 0.020 dB/connector

SM: -0.284 ± 0.014 dB/connector





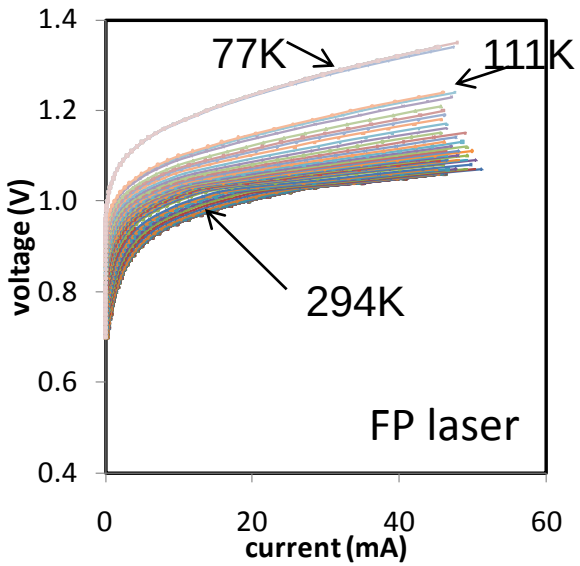


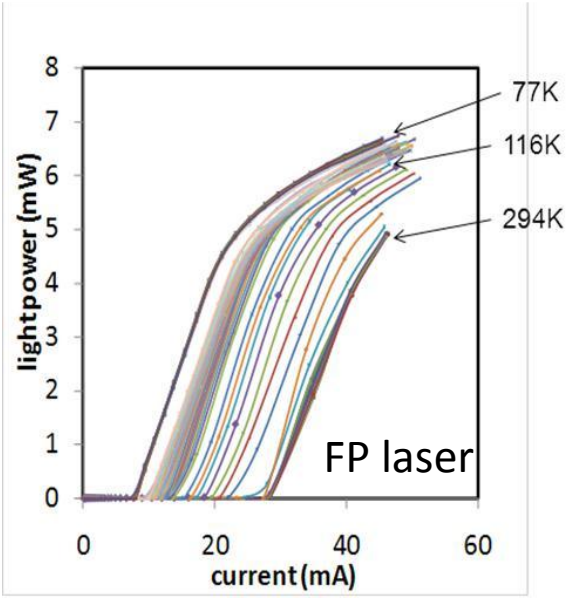


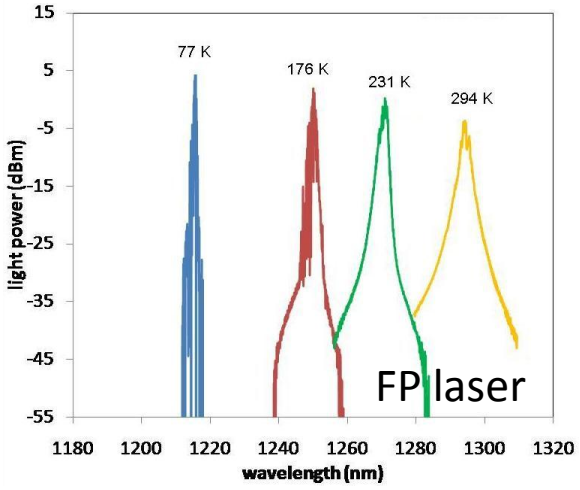
Optical Links - Laser diodes

- A vertical cavity surface emitting laser (VCSEL) diode, a distributed feedback (DFB) laser diode and a Fabry Perot (FP) laser diode have been tested. **All diodes continue to lase from room temperature to 77 K**.

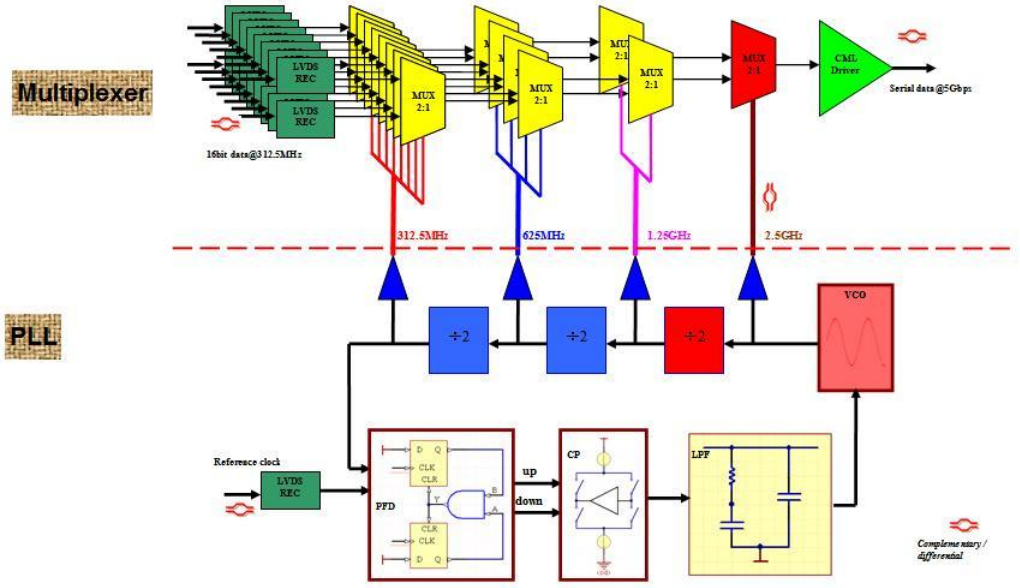
Change from RT to 77K	Vth	Ith	Light efficiency	λ
VCSEL	↑	↑	–	↓
Fabry-Perot (FP)	↑	↓	–	↓
Distributed feedback (DFB)	↑	↓	↓	↓

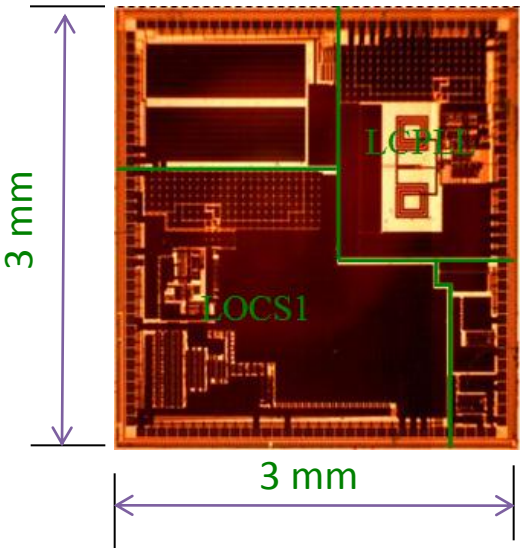






Optical Links - A serializer ASIC





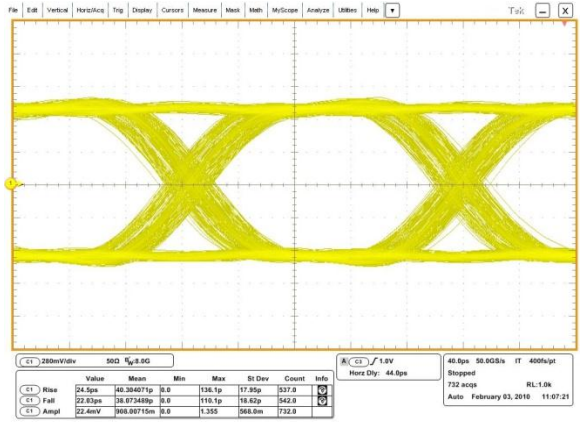
- Process: fabricated in a commercial 0.25 μm Silicon-on-sapphire (SoS) CMOS technology
- Input: 16 bit parallel data and 1 clock, LVDS
- Output: 1 bit serial, CML
- Operation range: 4.0 – 5.7 Gb/s
- Power dissipation: 463 mW
- Total jitter at the bit error rate of 10^{-12}: 62 ps (peak-peak).

Optical Links – ASIC @77 K

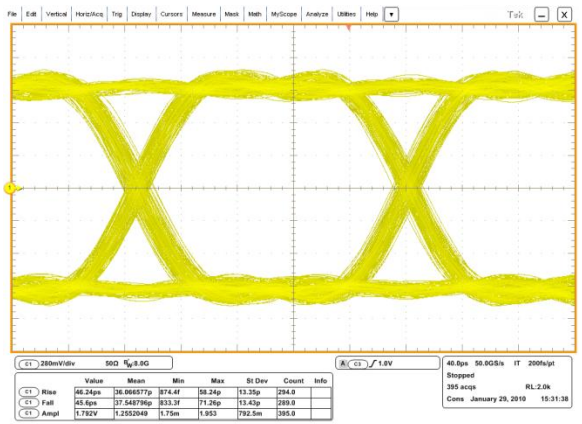
When temperature decreases

- Amplitude increases
- Speed increases
- Jitter decreases

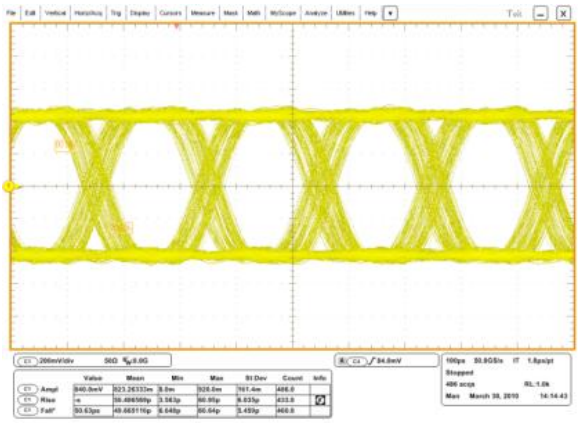
Room temperature, 5.2 Gb/s, 2.5 V



77 K, 5.2 Gb/s, 2.5 V

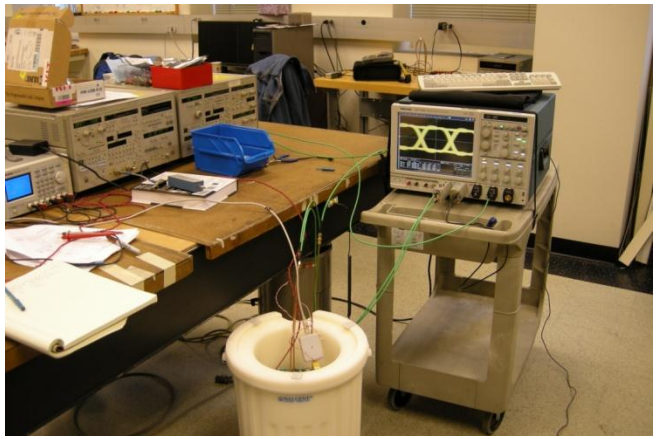


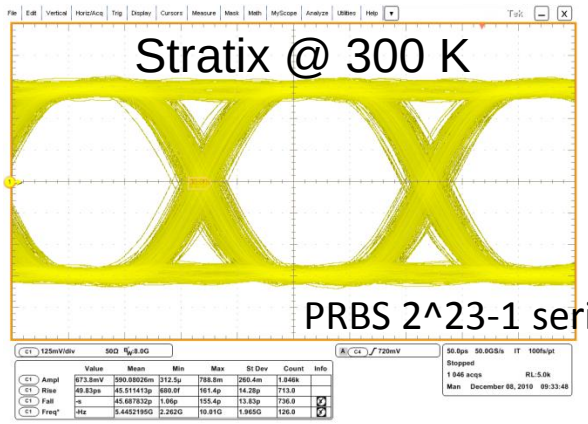
77 K, 5.2 Gb/s, 1.8 V

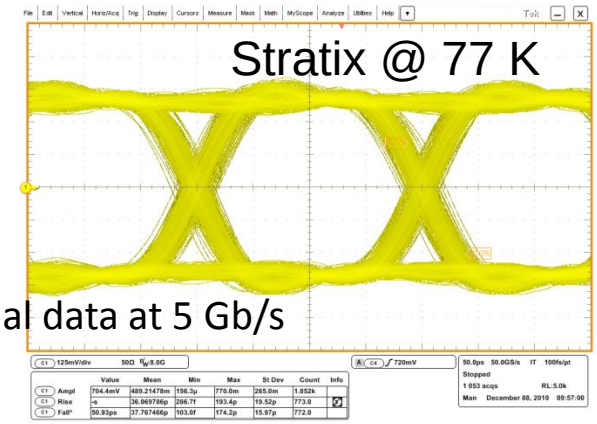


FPGA @ 77K

- **Motivation:**
  - An FPGA may be a low cost candidate for both electrical links and optical links.
  - Before the digital ASIC is available, an FPGA may be used for the small volume LArTPC prototype.
  - Two questions need to be answered: the cryogenic performance and reliability.
- **Setup:** Altera Stratix II GX EP2SGX90 and Altera Cyclone II EP2C20F484C8 in Liquid nitrogen
- **Results:** Both FPGA work at 77 K with no error in 20 minutes.







Resistors and capacitors

- **Motivation**: passive devices are needed in cold front-end electronics. For example, the decoupling capacitors and AC coupling capacitors from the wires to pre-amplifiers must be in liquid argon.
- **Setup**: Measured before, when dipped in the liquid, 20 minutes after taken out of the Dewar, and when dipped in the liquid again.
- **Results**:
  - **Resistors**: At 77 K, the resistance of the carbon composition resistors increase 19% and the resistance of metal element, wire wound, carbon film, thin film, metal film, thick film) change less than 7%.
  - **Capacitors**: Tantalum Electrolytic, C0G ceramic, film and mica capacitors change parameters significantly less than aluminum electrolytic, niobium oxide electrolytic capacitors, U, X, Y, Z ceramic capacitors.
  - **Repeatability**: Resistance and capacitance at 77 K are repeatable

	Type	Parameter change (%)
Resistors	Metal Element	-6.59
	Carbon Composition	19.10
	Carbon Film	6.40
	Thin Film	-0.21
	Metal Film	0.08
	Wire wound	0.15
	Thick Film	3.48
Capacitors	Al electrolytic	-100%
	NbO electrolytic	-71% ~ -39%
	Ta Electrolytic	-10%
	C0G/NP0 ceramic	-4.1% ~ 0.35%
	U, X, Y, Z ceramic	-24% ~ 94%
	Film	-13% ~ 3.8%
	Mica	-0.35% ~ -0.12%

Conclusion

- We have studied the cryogenic performances of
  - LVDS driver and CAT5E twisted-pair cables
  - 16:1 serializer ASIC, laser diodes, optical fibers, and optical connectors
  - FPGAs
  - Resistors and capacitors
- We don't see any show stopper in both electrical data links and optical data links.
- Some components (e.g., laser diode drivers) have not been studied yet.
- So far we've studied only the cryogenic performance and just started considering another important issue, the reliability.