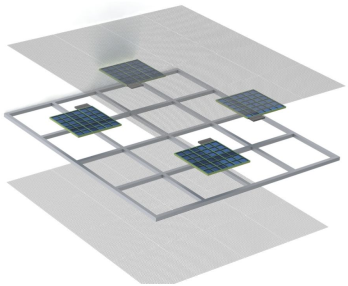
Analog Optical Transmitter

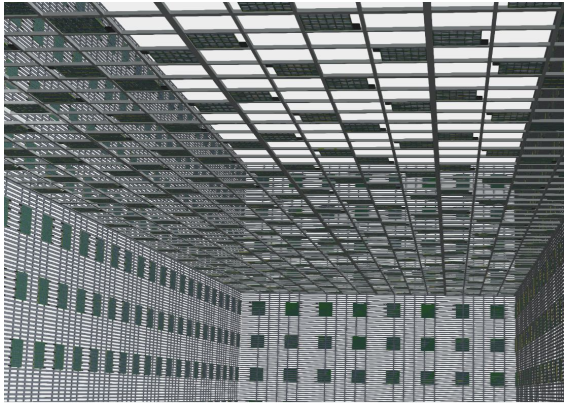
B. Courty,J. Dawson, D. Nita, S. Sacerdoti
APC - Paris

DUNE FD-2 workshop, 2021/07/27

Introduction

- Baseline proposal of the Far Detector 2 includes photo-sensors on the cathode
  - at 300kV, non conductive materials need to be used for power lines and signal redout
- Analog optical transmission of the SiPM signals:
  - no commercial optolink is rated to work in cryogenic temperatures but..
  - previous investigations showed encouraging results
  - The DarkSide experiment has a functioning single channel prototype → they have slightly different requirements but their experience has provided valuable input for us
  - feasible within the tight timescale and constrained budget available





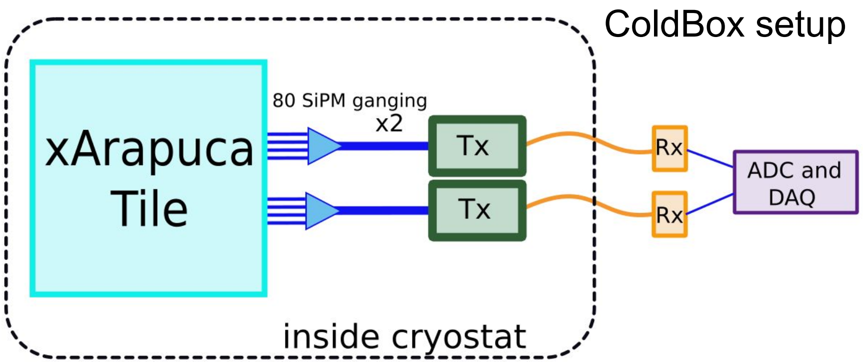
Single channel prototypes

DarkSide

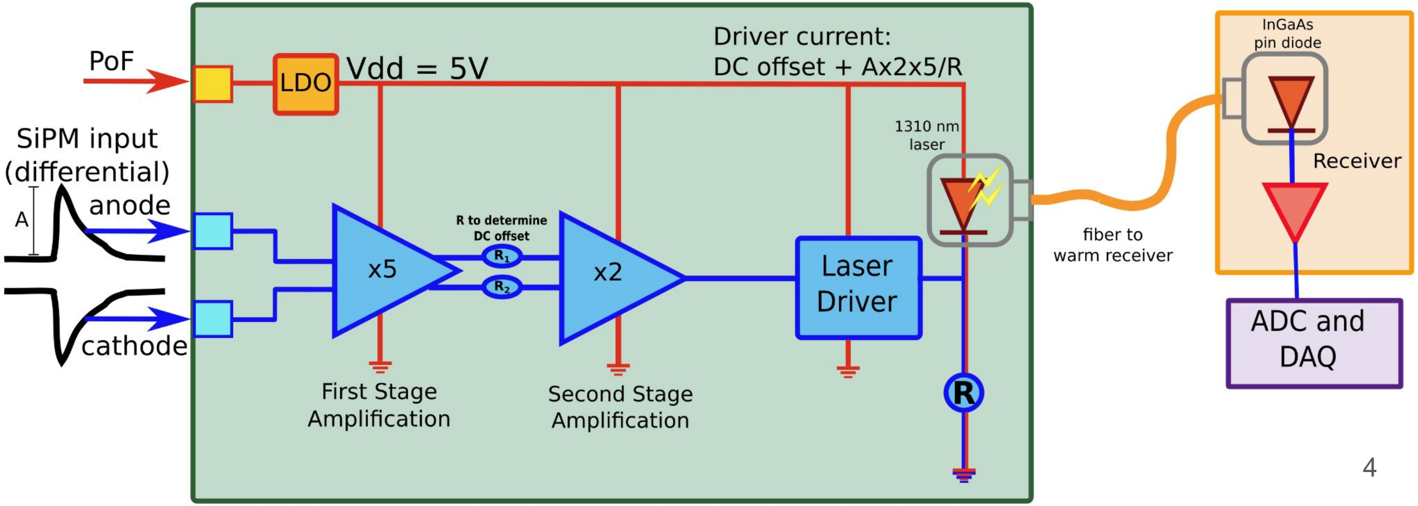
Introduction

- Target: analog optical transmitter in LAr + analog optical receiver @RT (+ digitization)
  - low noise, high bandwidth amplification and laser driver circuit
  - design based on selected discrete components that work in cryo
    - limited availability of fast low noise components
  - can transmit SPE signals but also fairly large (1000PE signals)
- Low risk scheme:
  - feasible in the short timescale required
  - Low cost and reduced size allow to have 1 channel per xARAPUCA (2 in the coldbox)
    → channel failure does not imply a large loss
    → no copper wires running through cathode (avoids risks due to discharges)
  - low power consumption and single Vdd value needed → well adjusted for PoF use
- Requirements:
  - Large dynamic range: SPE - ~1000 PE
  - Bandwidth: SiPM signal rise time ~20ns → at least 20 MHz analog bandwidth
  - SPE S/N > 4

General Scheme

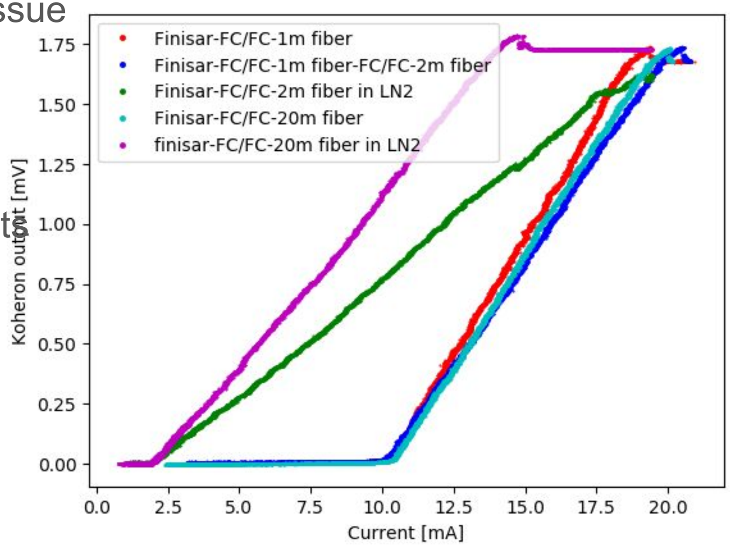


SiPM ganging:
Grouping in (4x5 passive)x4 active
Differential signal output, AC coupled
SPE expected signal level ~80uV
See Dante's presentation



Light Source + fiber coupling

- Laser over LED → same threshold, higher efficiency
- Existing literature on different types of lasers working in cold
  - focusing on 1310nm Fabry-Perot lasers
  - interesting feature: lower threshold current (from 10mA to ~2mA)
  - → a DC offset needs to be set above this threshold to operate in the linear regime
  - expected shift in wavelength in cold should not be an issue
- Laser to fiber coupling is a major concern
  - ~30% light loss in each laser-fiber or fiber-fiber connection
  - FC connectors show consistent behaviour between tests → good candidate
  - No significant loss in longer fibers (20m tested)
  - current fibers seems good enough for coldbox test but further investigation is probably needed.

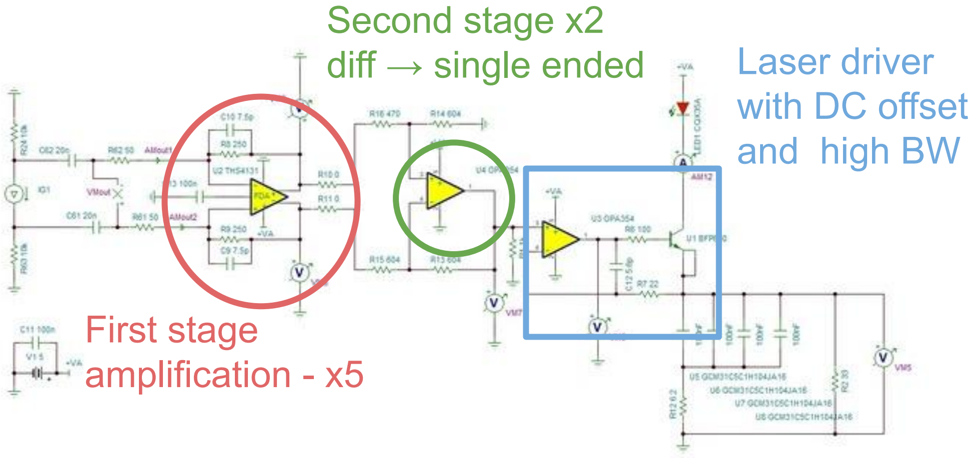


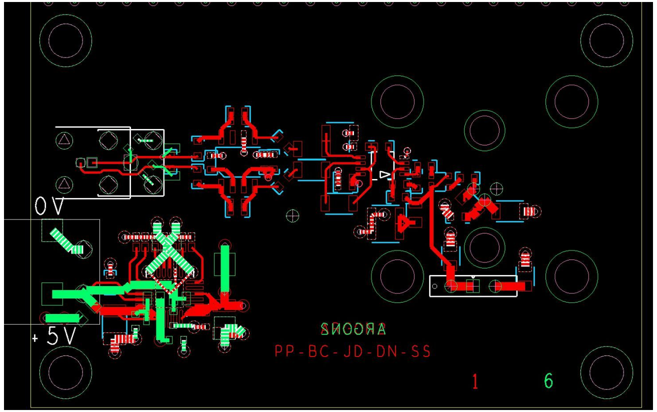
- Looking into lasers in receptacles with FC connector
  - candidate bought from Lasermate
  - on-going process to acquire various lasers from GySuntec in Chin

Analog Transmitter for SiPM signal

Development at APC: analog transmitter circuit:

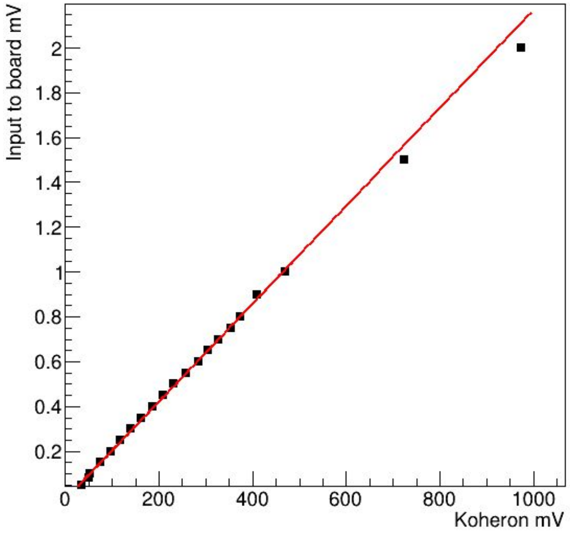
- differential input from SiPM ganging board
- about x10 amplification in two stages → latest test done at x20 amplification
- laser driver (in-house designed):
  - selected discrete components for high bandwidth, low noise and probability to function in LAr.
  - Benefit wrt integrated circuits: if component works once, very low risk it will stop working.

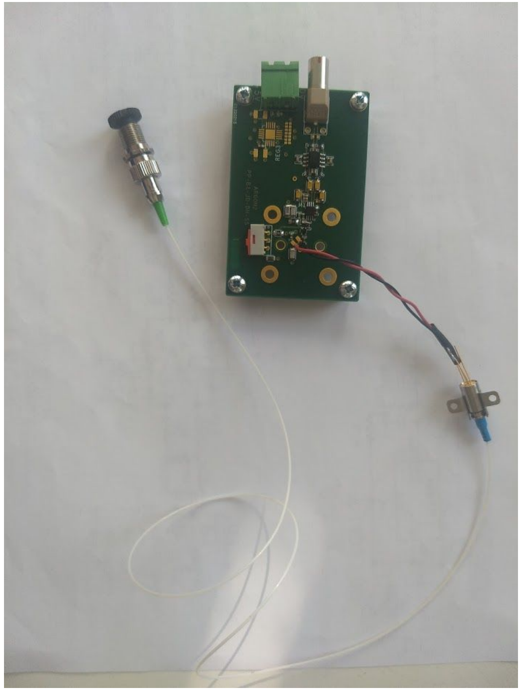




Board characterization

- Current board equipped with a 1310nm, 2mW pigtailed laser
  - additional light loss in pigtail
- Equipped with a switch to operate both at RT and in LN_2
  - laser needs different offset
- Linearity looks good for small signals
  - measured using a function generator at the input





- 2 boards have been instrumented at APC and are used for different tests
- 2 boards have been sent to Fermilab
- A second version should be ready before the coldbox test

The search for the SPE

The noise level was found to be higher in cold. Investigations are on-going to try to decrease it.
After increasing the gain (x20) we see nice SPE signals with all the system submerged in LN_2.
Higher gain (x10 in first stage) decreases the bandwidth to ~20MHz (but probably still ok).

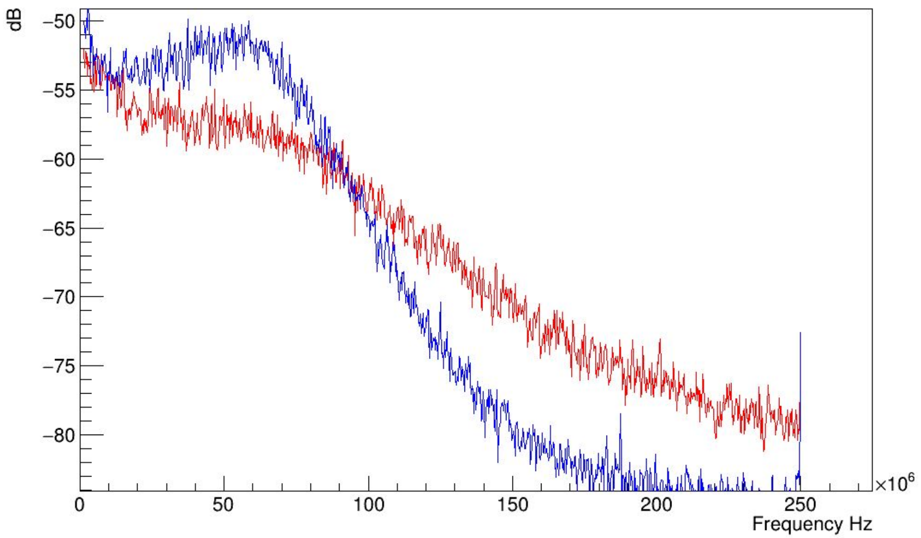
in LN_2

4 SiPMs →
SMA→ LEMO
→ driver board →laser

→ commercial receiver

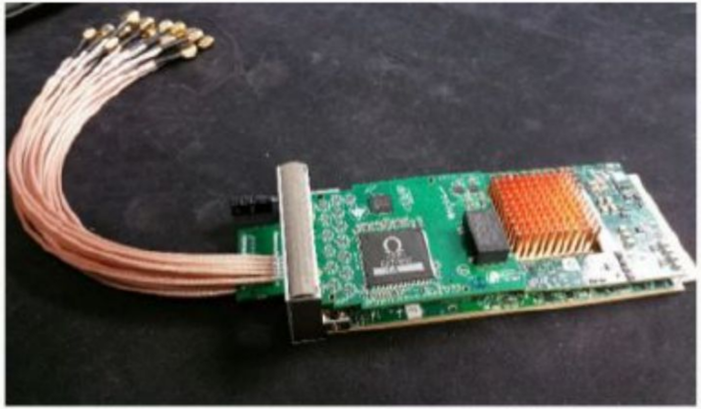
Board characterization

Noise spectrum: measurement with input shorted (no input signal)
At room temperature and in LN2.
The bump around 50 MHz could be the cause of increased noise seen in cold, might be reduced with small circuit modifications.



Receiver and digitization

- First tests done with an off-the-shelf receiver
  - now developing an in-house receiver with an InGaAs pin-diode and fast amplification
  - using off-the shelf Koheron PD100 for coldbox test is an option
    → 100 MHz BW,~3mVpp noise level,
    → but saturates at 600uW



Previous development for Dual Phase

- Digitization at warm at the coldbox test could be done using the PDS readout developed for DualPhase
  - μTCA standard → following top electronics design
  - commercial motherboard with a StratixIV FPGA
  - custom daughter board:
    - 14 bit ADC chosen (AD LTC2155-14) could digitize at 100MHz
- Data can be acquired using an oscilloscope
  → could be good for debugging + other studies

Conclusions

- Focus on SPE since it seemed the hardest deliverable
    - SPE signal from old SiPM board transmitted with what seems an acceptable S/N
    - still room for balance between gain, bandwidth, noise level
    - should be tested using the SiPMs acquired for the coldbox test
        - necessary gain depends on SPE signal size
- Noise level in cold is found to be higher than in RT
    - several possible explanations being examined
    - can be compensated with higher gain, but trying to reduce it
- Next: start evaluating the dynamic range for larger signals
- Calibration: necessary to evaluate drift in laser power/other possible changes
    - SPE signal could be used, as intended by DS
    - alternatives to evaluate: known signal using PoF? use photodiode from laser assembly?

Back Up

SPE signal with SSP (x18 amplif) (from Dante)