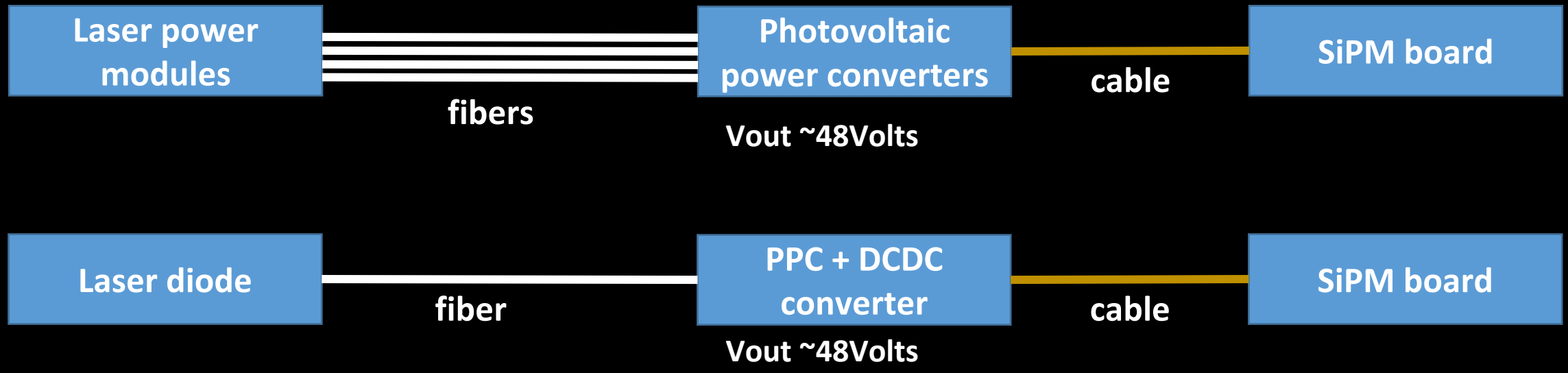
First R&D

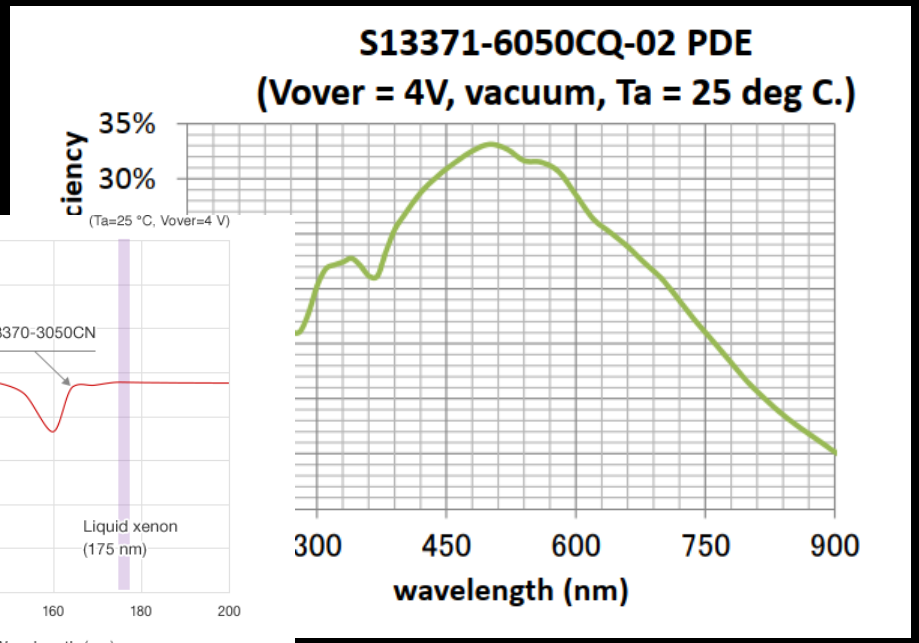
Testing power over fibers technologies to bias Silicone Photomultipliers

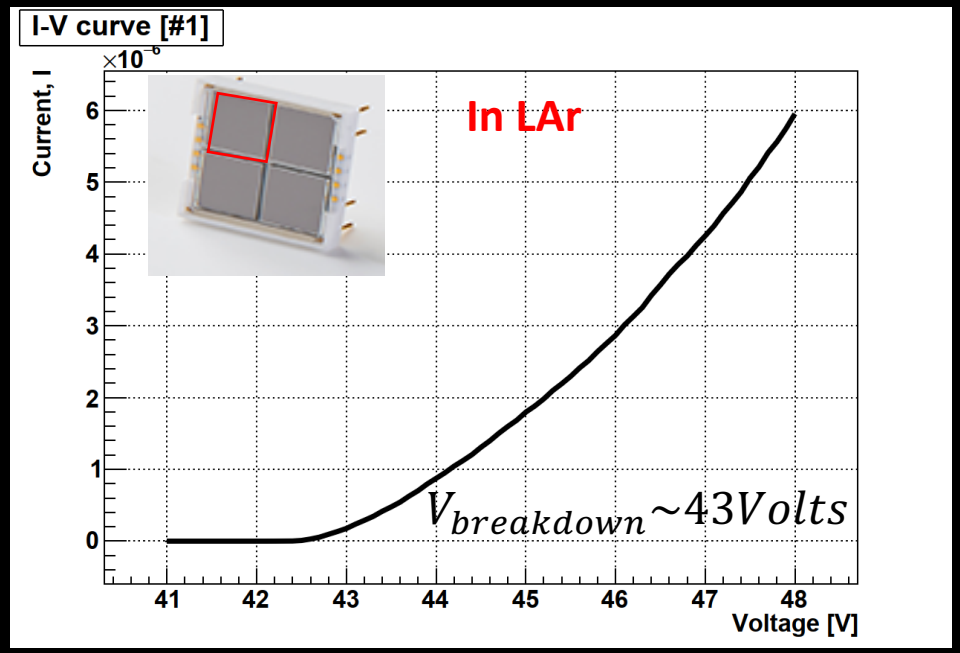


- Performance of the PoF
- Long term stability of the system and voltage output
- Light leakage along the fibers in LAr
- Signal recording from SiPM
- Heat dissipation and bubble formations in LAr
- Interference with HV

Reminder on SiPM arrays:

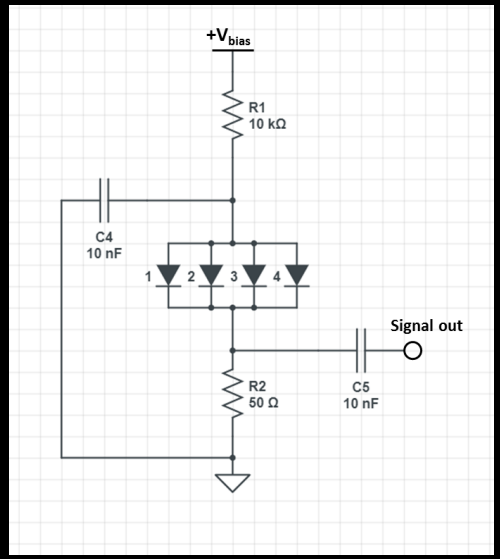
Photon detection efficiency





- We use LAr and LXe sensitive VUV4-SiPM arrays in the tests
- We have measured break down voltage of ~43 Volts in liquid argon
- We need to get an output voltage of 46 to 48 Volts from power over fiber units to bias the SiPM arrays

$$V_{operating} = V_{breakdown} + 5V \sim 48Volts$$



Power over fiber system [1]

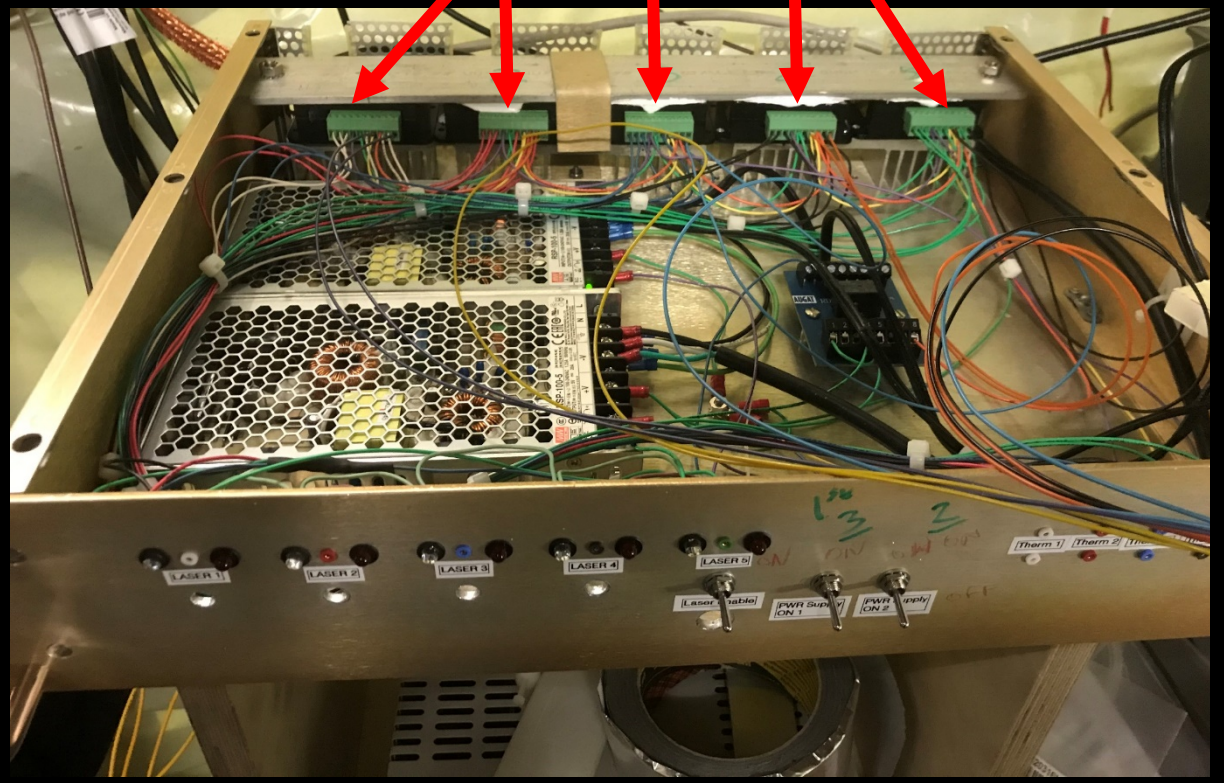
Laser power modules:

- Five power modules installed into PoF units
- Supply voltage in the range of 3.0 to 5.5 Volts
- 976 nm laser source
- Up to 3.5W of laser power out
- Adjusted power levels by changing setting resistors
- 3 m multimode fibers (62.5□m, NA 0.27) with FC connectors

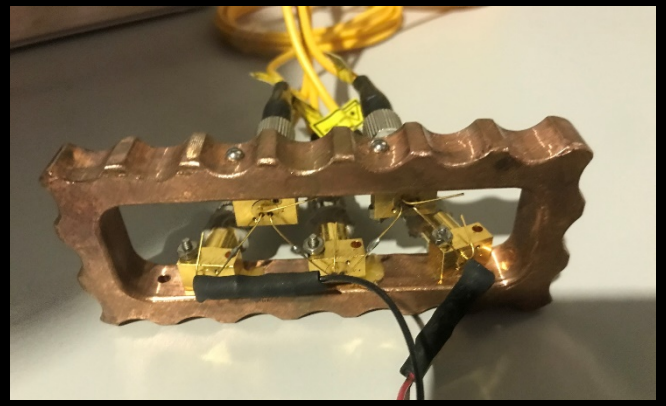
Photovoltaic power converters (PPC):

- Si-based vertical multi-junction photovoltaic cell
- Optimized for 915 nm through 980 nm laser source
- Efficiency at 1W input is ~23%
- Up to 12 Volts output for one PPC in LAr temperature
- Four PPC units in series to get 48Volts of bias voltage for SiPM arrays used in the test

Laser power modules



Photovoltaic Power converters (PPC)



Power over fiber system [2]

Laser diode:

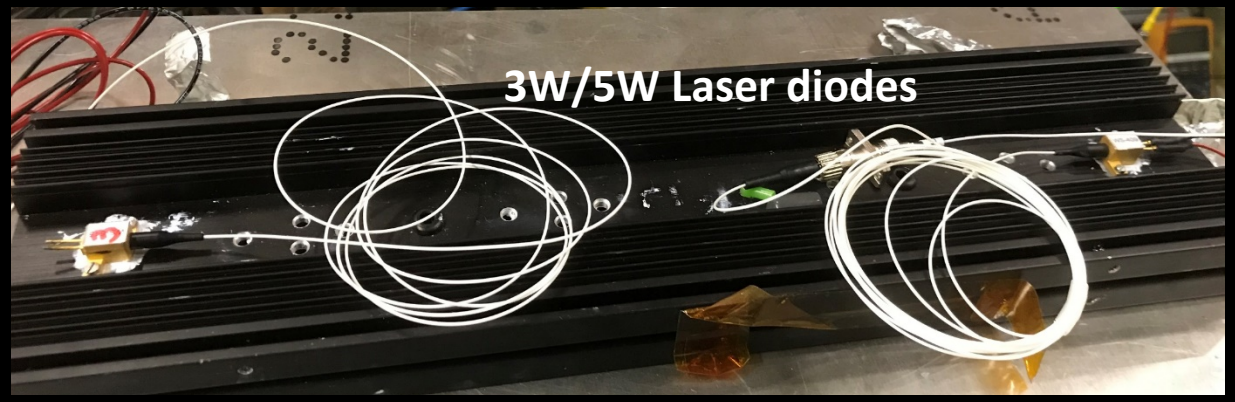
- Two options: 3W and 5W laser diode
- 808 nm laser source
- Operating voltage of 1.9 V and current of 2.7 A
- 1 m long multimode fiber (105 □m, NA 0.22) with FC connector

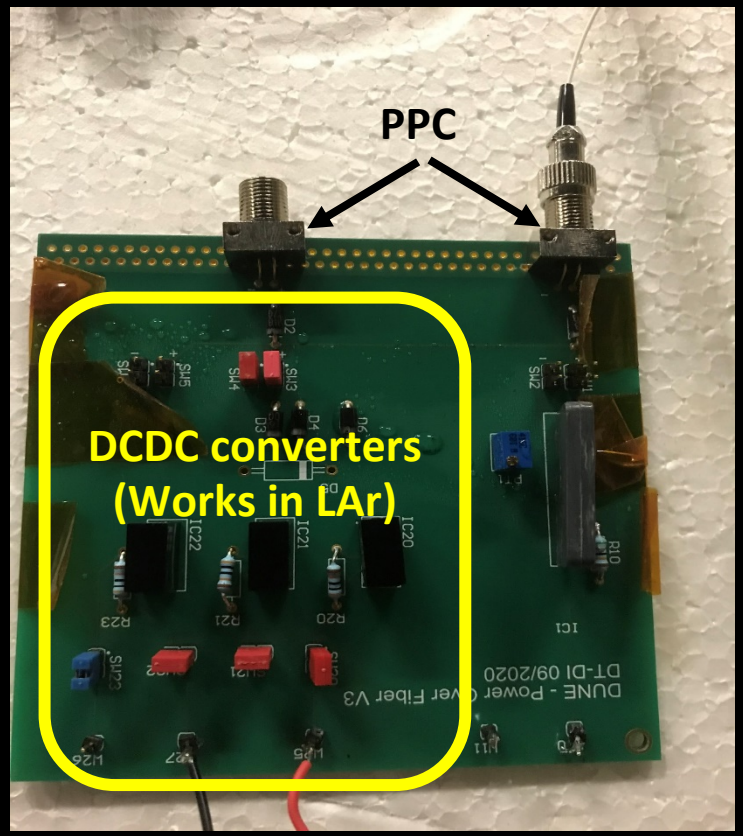
Photovoltaic power converters:

- Maximum voltage output of 6.5 volts
- Maximum power of 600 mW

DC-DC converter circuits:

- Isolated Murata DCDC 5V to 24V
- Two DCDC in series provides 48 Volts of output





50L test in bldg.182

What is done:

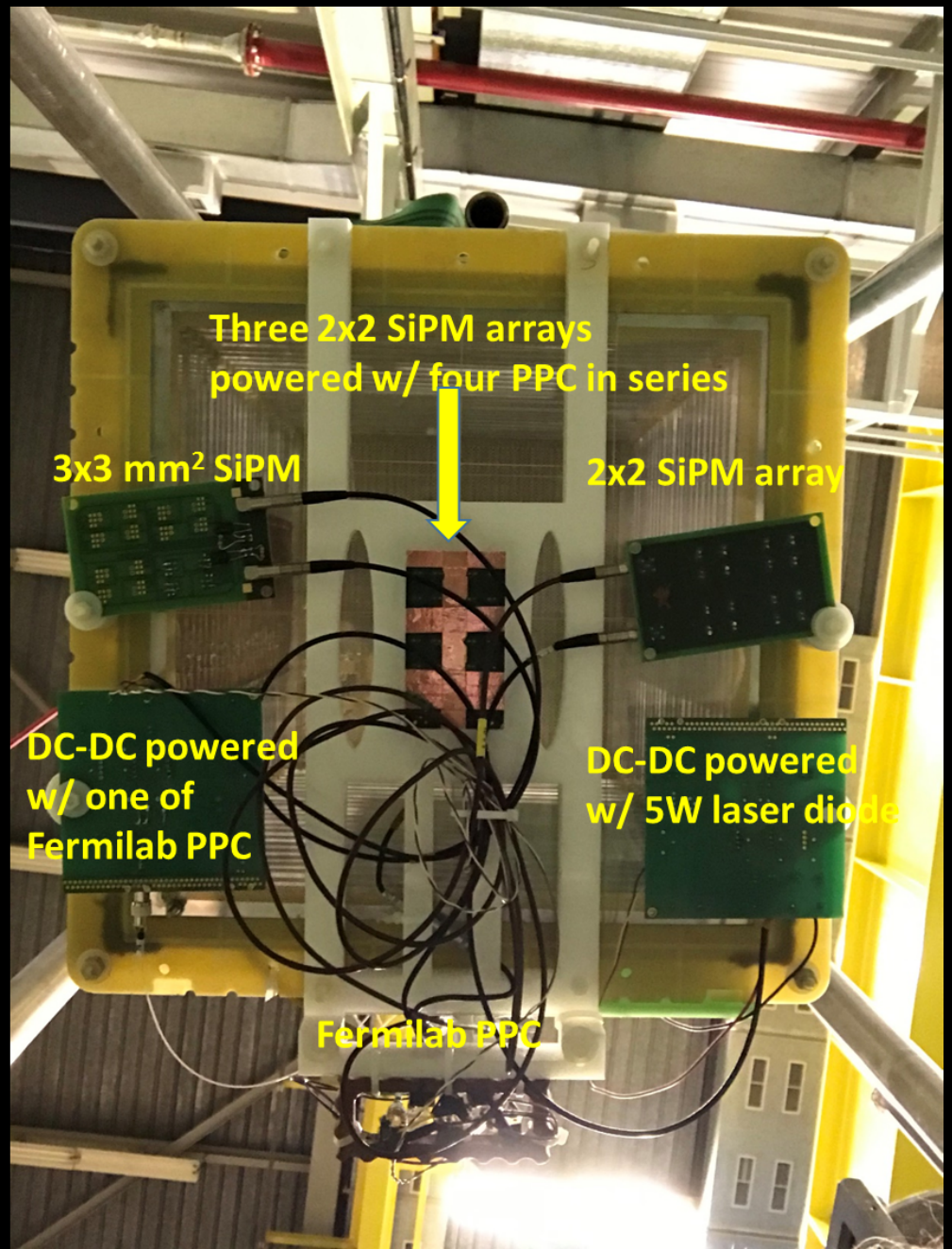
- December 16 – 18: Cryostat prepared for the test and vacuum started (see previous slides circulated on Friday, December 18)
- December 21:
  - cooling started around 11:00
  - Filling cryostat with liquid argon started around 12:00
  - Checking the noise on TPC charge readout
  - Checking PoF units

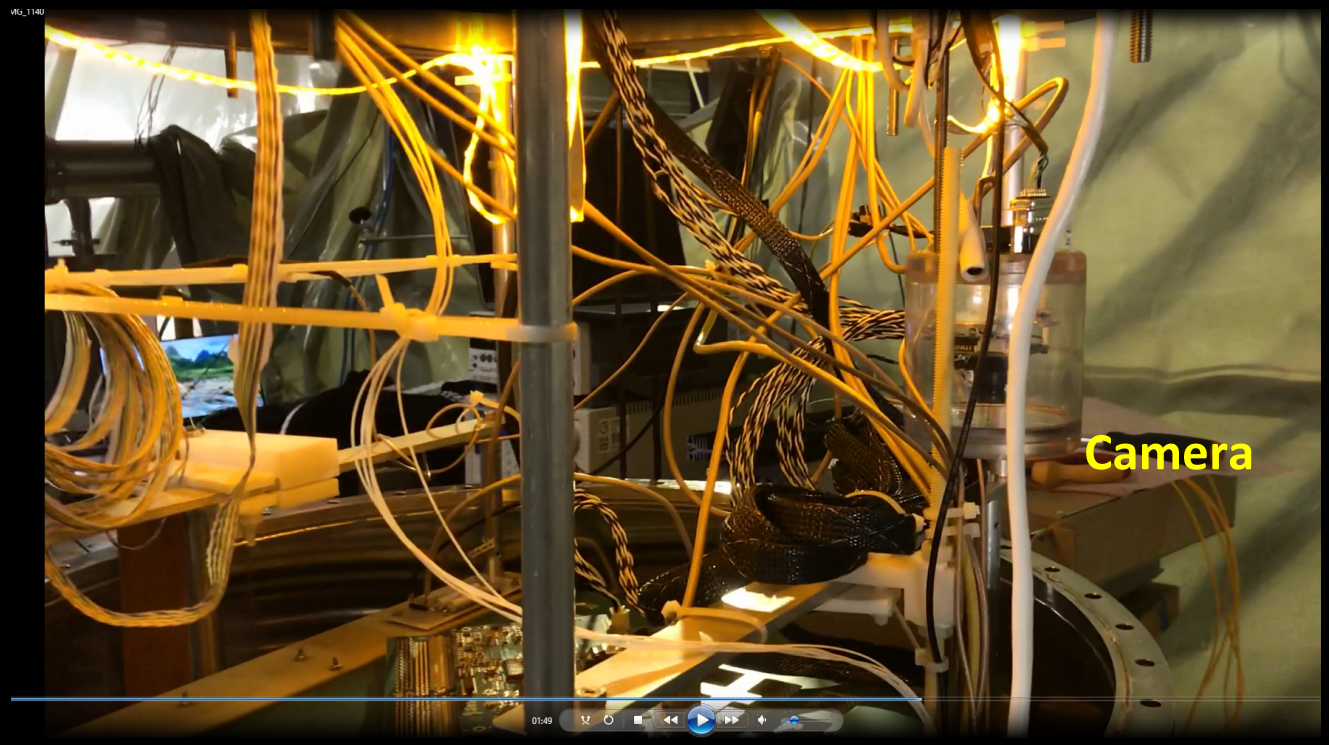
- December 22:
  - More tests with PoF units
  - Noise study with TPC
  - Stop the test

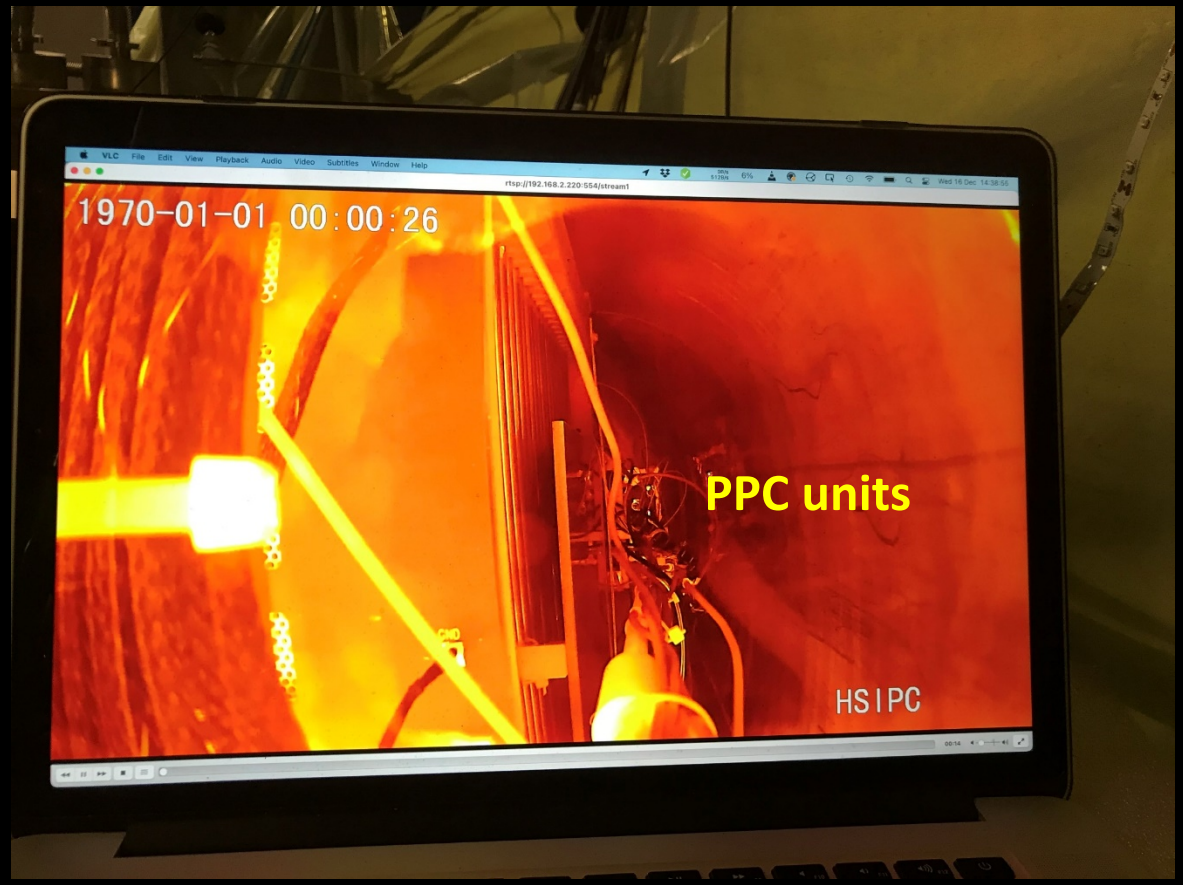
- December 23:
  - Open the cryostat for further investigations

- December 23 to 30: tests on SiPMs and fibers

Preparation for 50L test (December 16 to 18)







- Camera inserted inside the cryostat looking down to PPC units

December 16:

- Starting vacuum at 19:25

December 17:

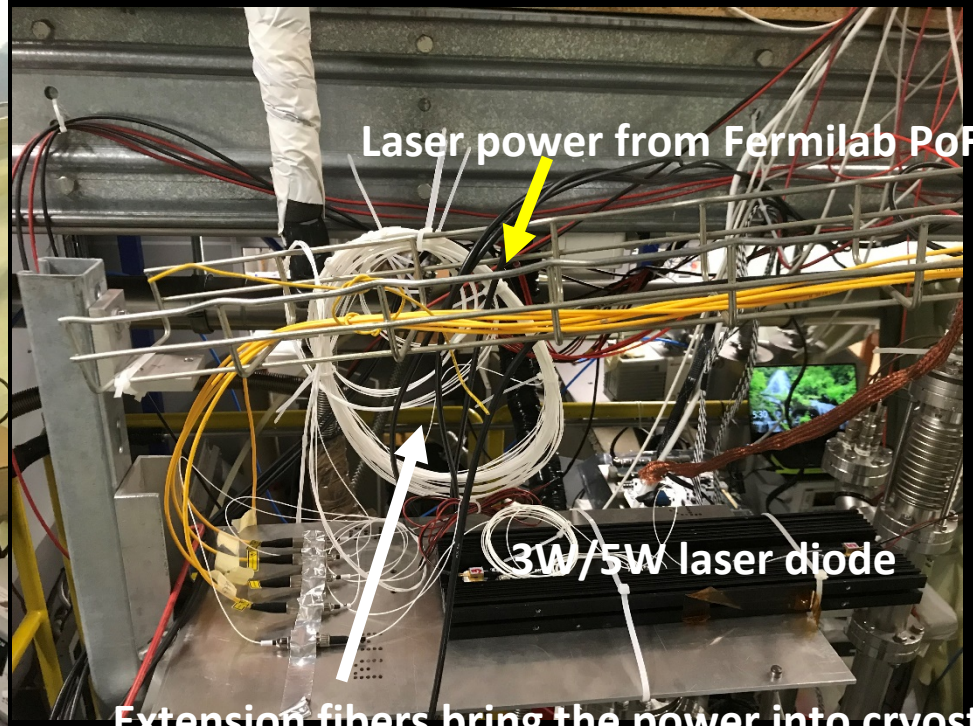
- Found leaks on two flanges: fixed!
- Vacuum restarted at 13:00

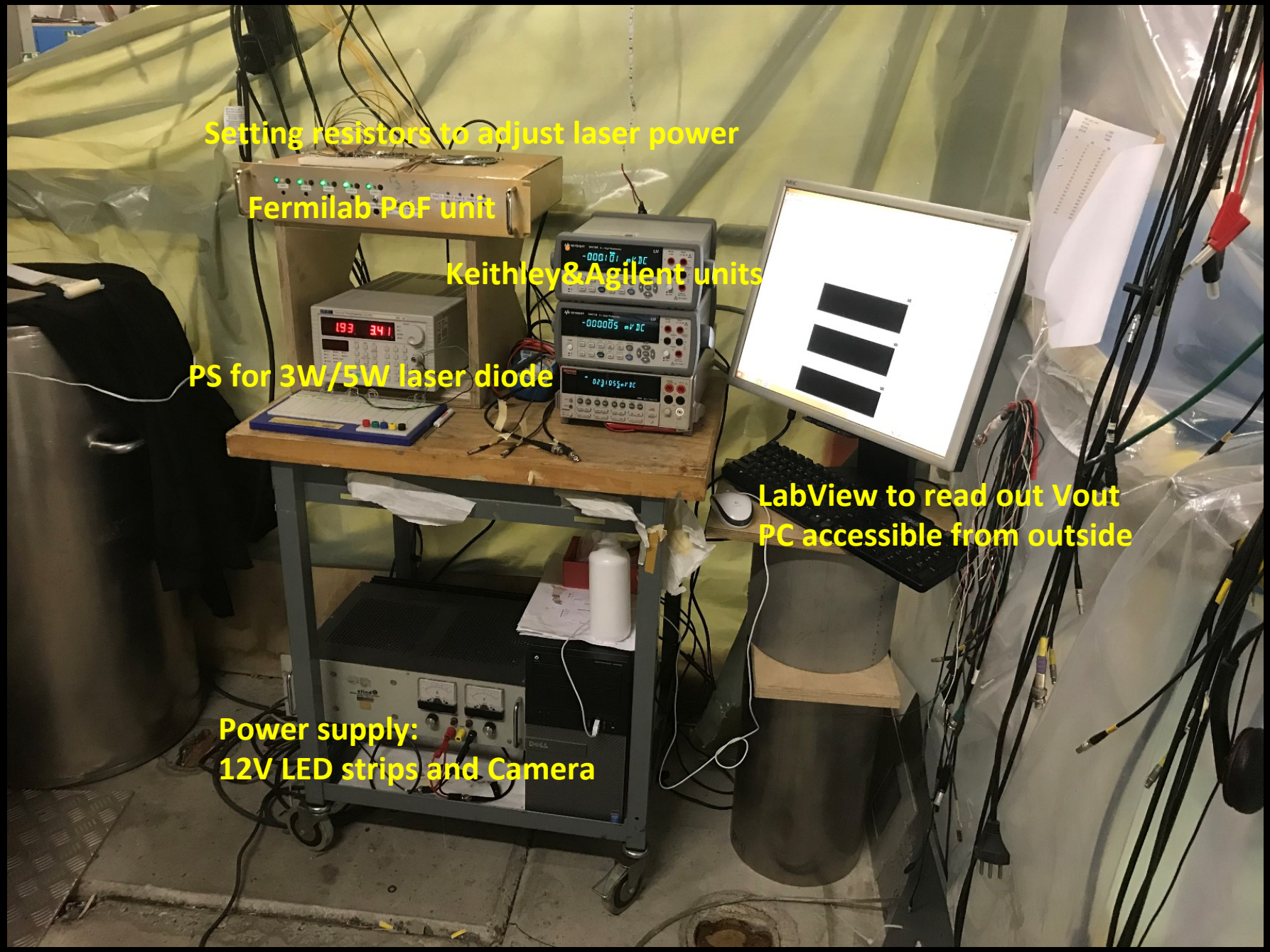
December 18:

- Leak test with He-Leak detectors
- All feedthroughs tight and no leaks
- Cabling done
- Electrical connection checks done

Keep vacuum running during the weekend!

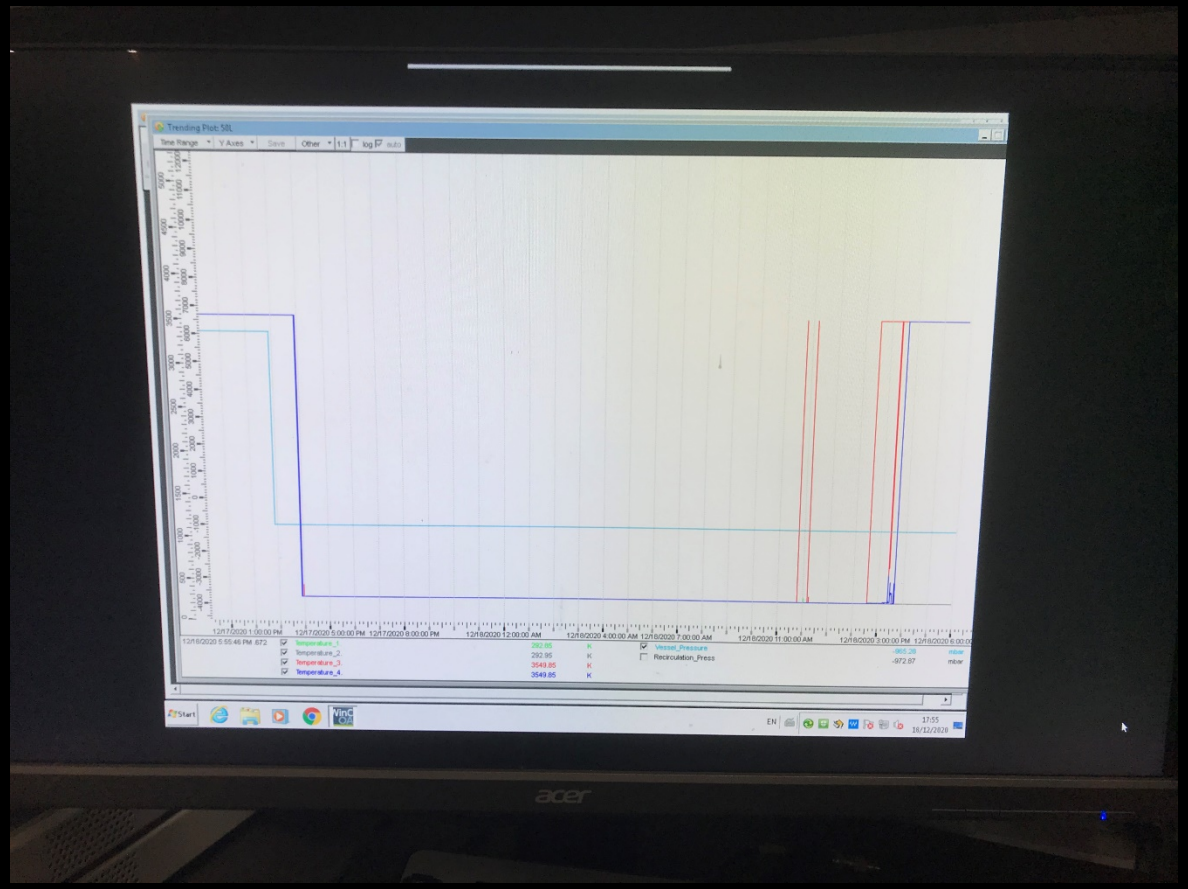

Scintillator slab


Laser power from Fermilab PoF
3W/5W laser diode
Extension fibers bring the power into cryostat

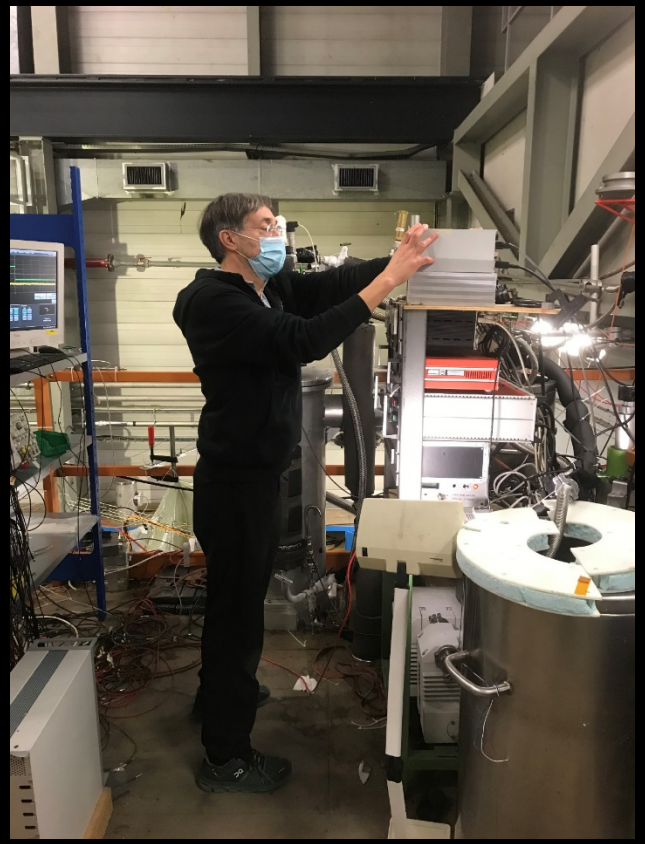

Setting resistors to adjust laser power
Fermilab PoF unit
Keithley&Agilent units
PS for 3W/5W laser diode
LabView to read out Vout
PC accessible from outside
Power supply:
12V LED strips and Camera

TPC electronics

Slow control: pressure and temperature

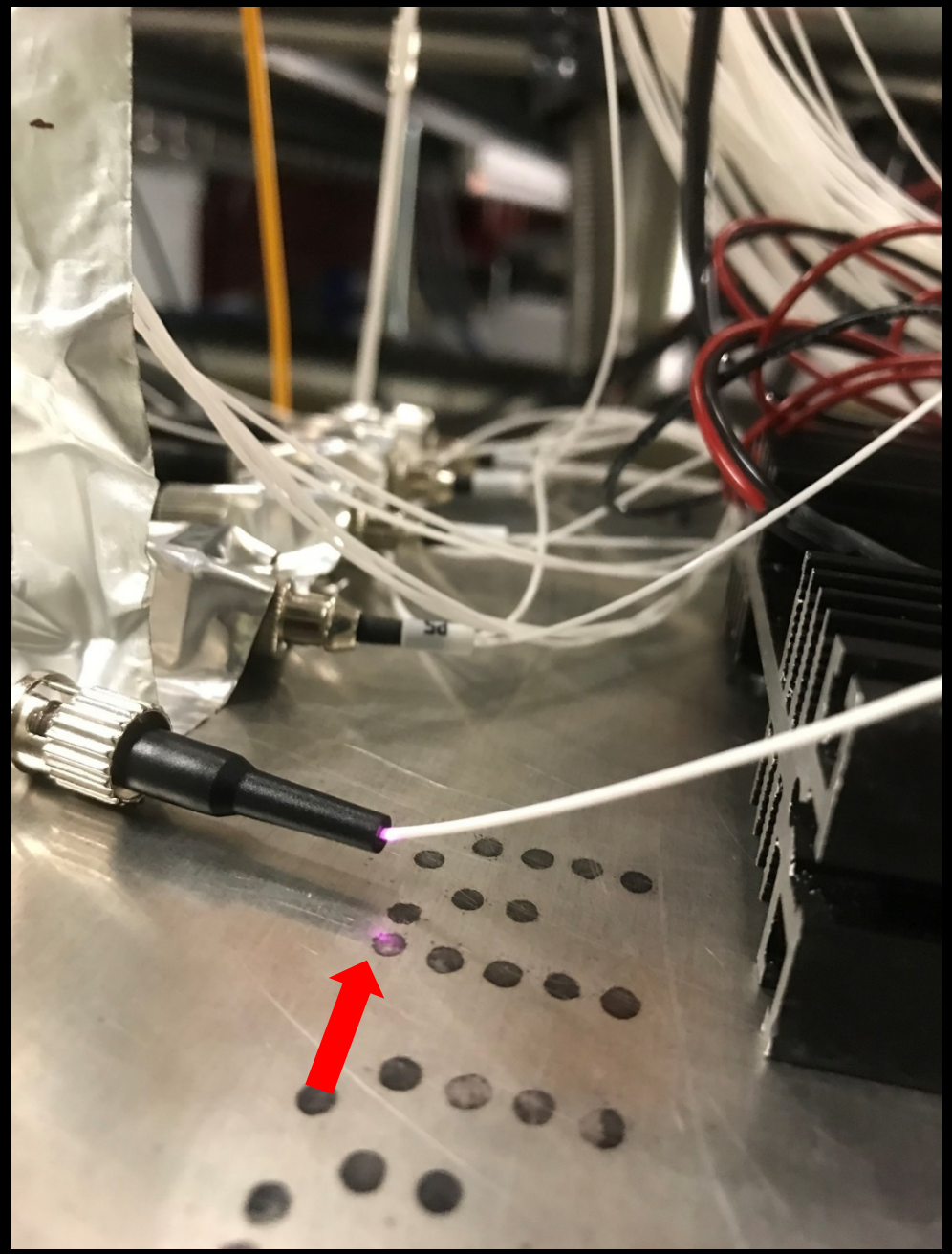


Cooling and filling the 50L-cryostat (December 21)



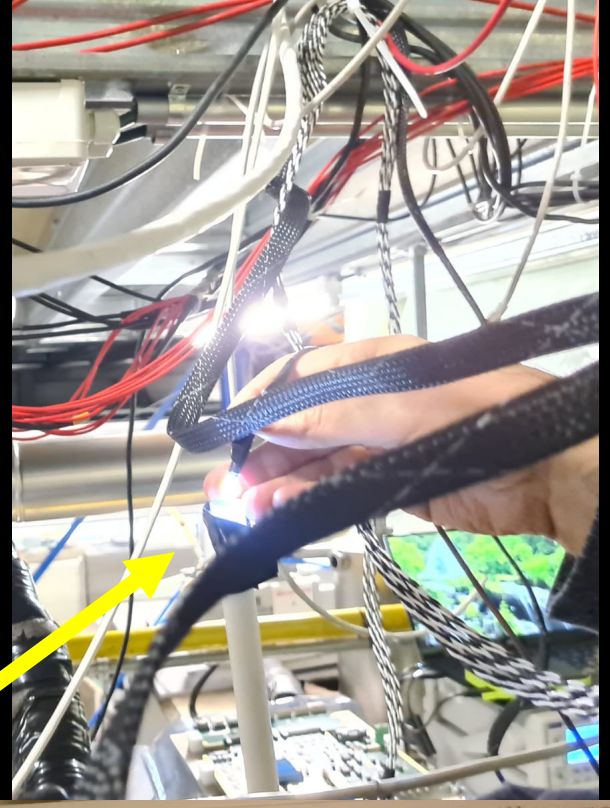
Checking the PoF units 1:

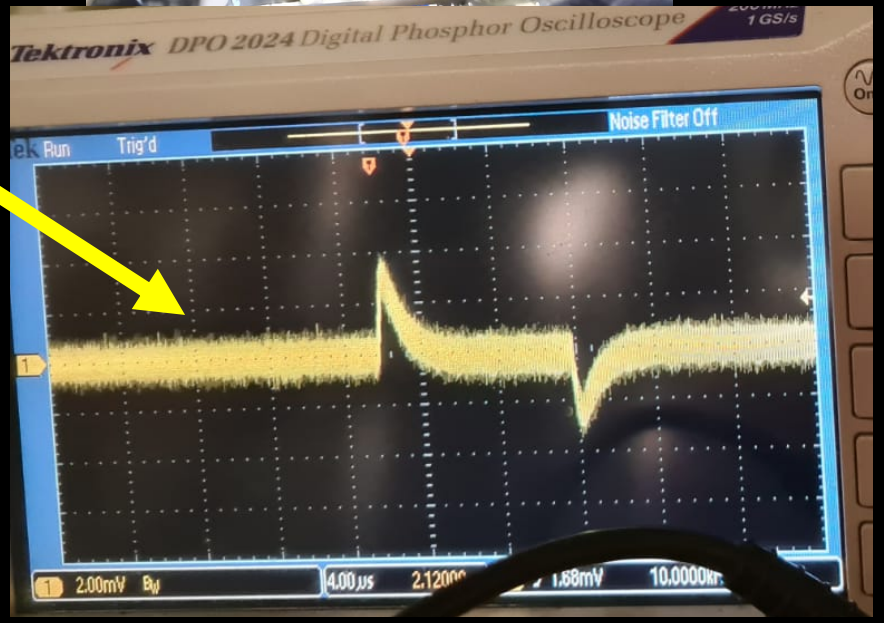
- We found the fiber of the 5W-laser diode got broken! (Friday was working without any problem)
- Replaced with spare one (thanks Xavier and CERN Fireman people)
- This laser diode is used together with 5V-DC-DC circuit. We read out >=48 Volts from feedback cable.
- One VUV type SiPM array is used in SiPM board. We could not get any signals from the SiPM. We found that the signal cable malfunctioned (to be investigated once we open the dewar).



Checking the PoF units 2:

- Fermilab PoF units, 4-PPC in series with 360 Ohm setting resistance, we read out 48 Volts from feedback cable.
- SiPM board has three VUV type SiPM arrays. We do not see any signal from SiPM both using self and external trigger (coincidence of two scintillator slabs located on the left/right side of cryostat, they also move to the top of the cryostat to check with vertical muons).
- We try to inject pulsed LED light via fiber installed on the cryostat. With high intensity we start to see signal from SiPM array!
- Why do not we see argon scintillation light? (we will discuss this question in coming slides)
  - VUV-SiPM has photon detection efficiency of 15% to LAr and 23% to LXe and ~40% to visible light





Checking the PoF units 3:

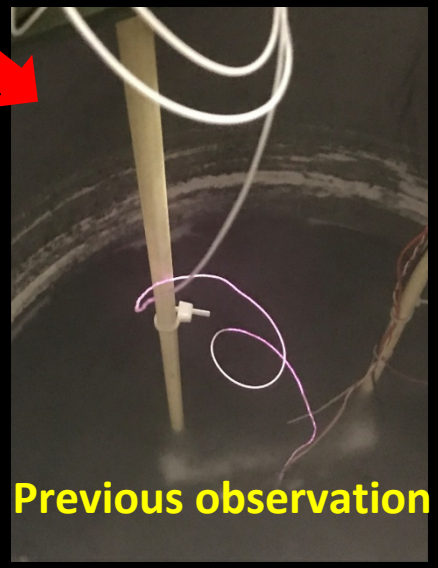
- 1-PPC from Fermilab PoF units connected to 12V-DC-DC circuit.
- 12V-DC-DC converters requires input current of 15 mA with no load ~48 Volts output voltage and 10mA output current
- When we have tested the full system in open air dewar, using 1.2k setting resistors and PPC#5 from Fermilab PoF units, we could get ~47 Volts of output voltage from 12V-DC-DC circuit. We had 11.6 Volts from PPC#5 as an input to 12V-DC-DC circuit. And in all test, the DC-DC circuit was floating in terms of grounding.
- From test in 50L, using the same settings, we could get maximum output voltage of 11.4 Volts from PPC#5 and 38 Volts from 12V-DC-DC converter!
- Are we loosing some power inside the cryostat? (we will discuss this question in coming slides)

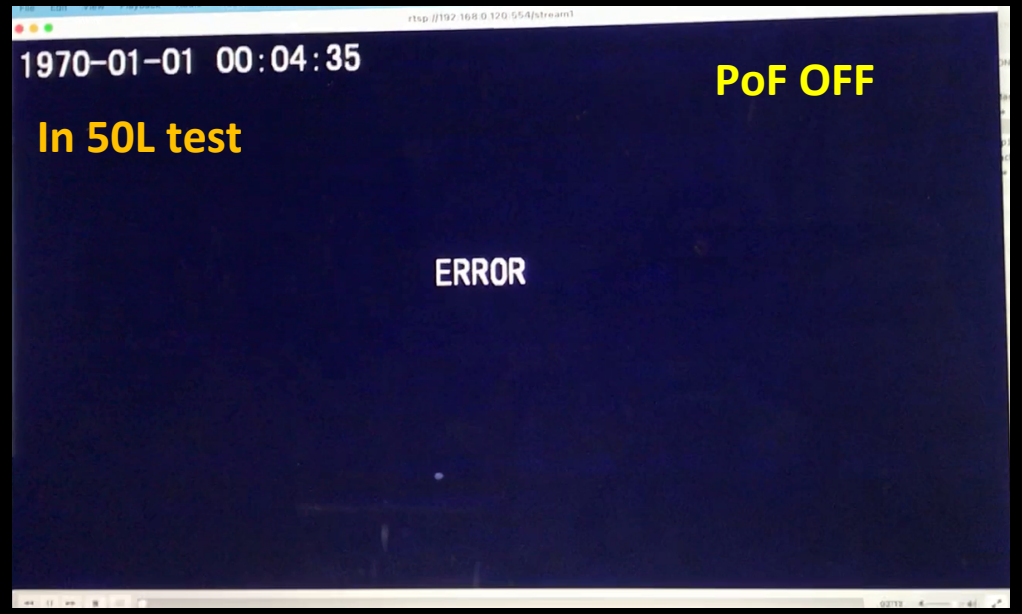
- Thanks to the presence of internal camera and its functionality at absence of its cover, we found that the light is diffusing out along the surface of the extension fibers (thin white fibers).

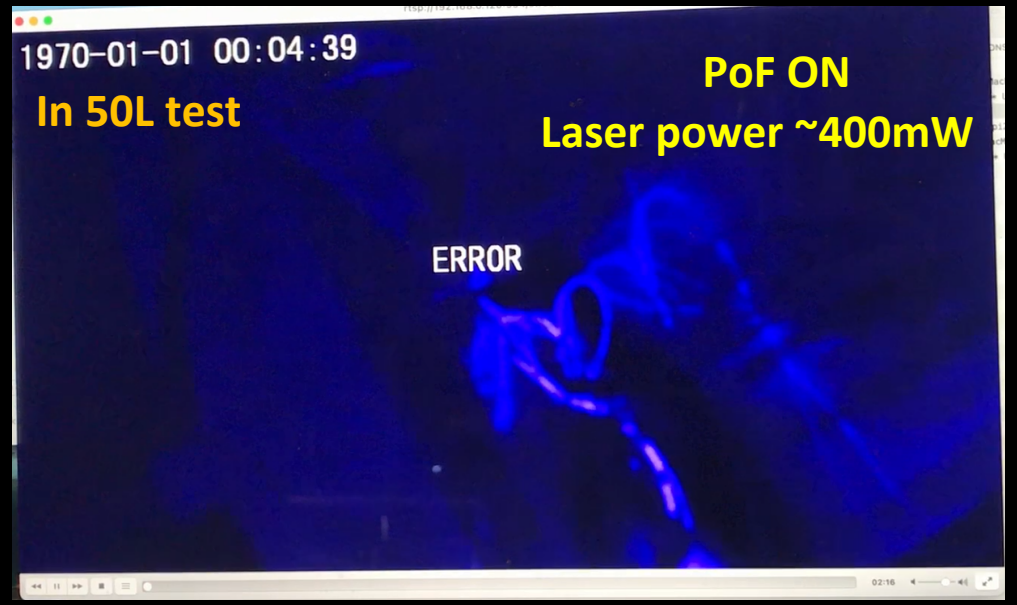
- Changing the setting resistors, the brightness of the light increased.

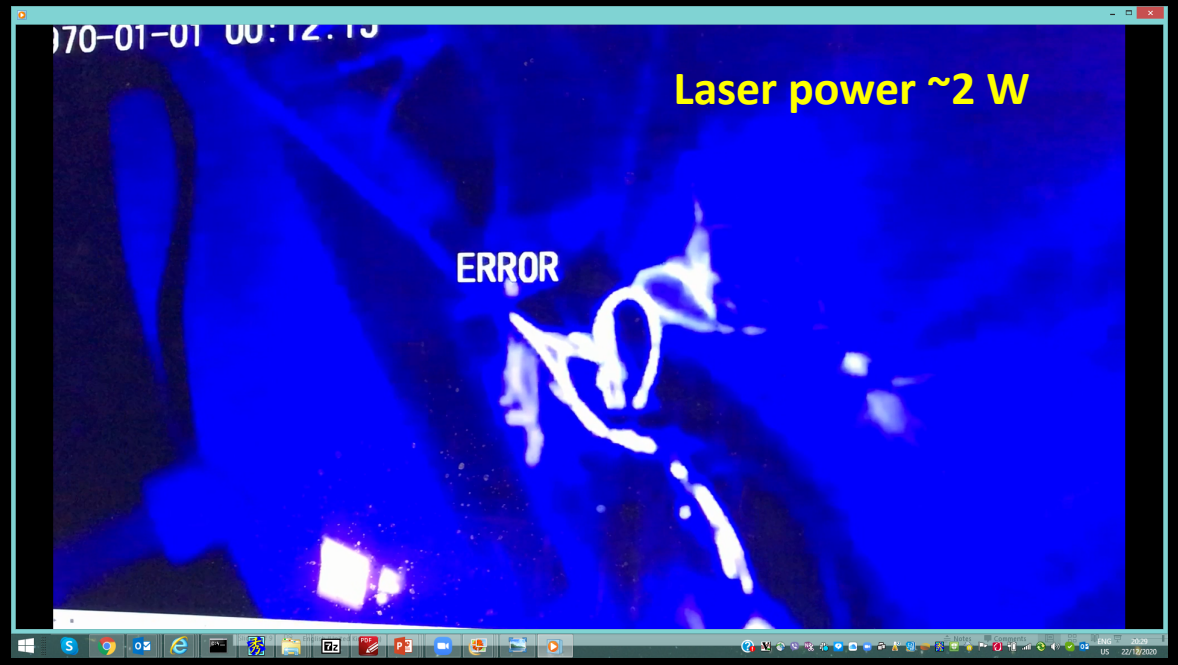
- Such a diffusion of the light along the fiber has been seen with 2.5W laser diode used w/ DC-DC circuit in LAr. It had a major impact on powering 5V-DC-DC converter which needs 20mA input currents.

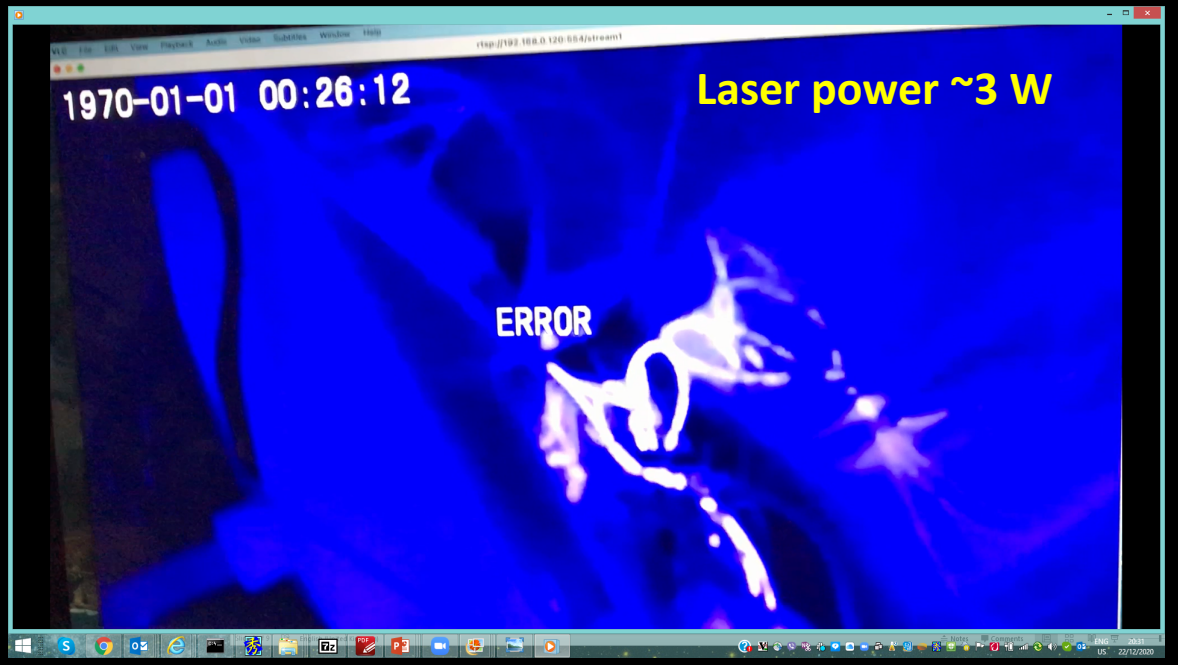
- We had the same test with extension fibers in open air dewar. It was only check by eye so no diffused light we have seen.







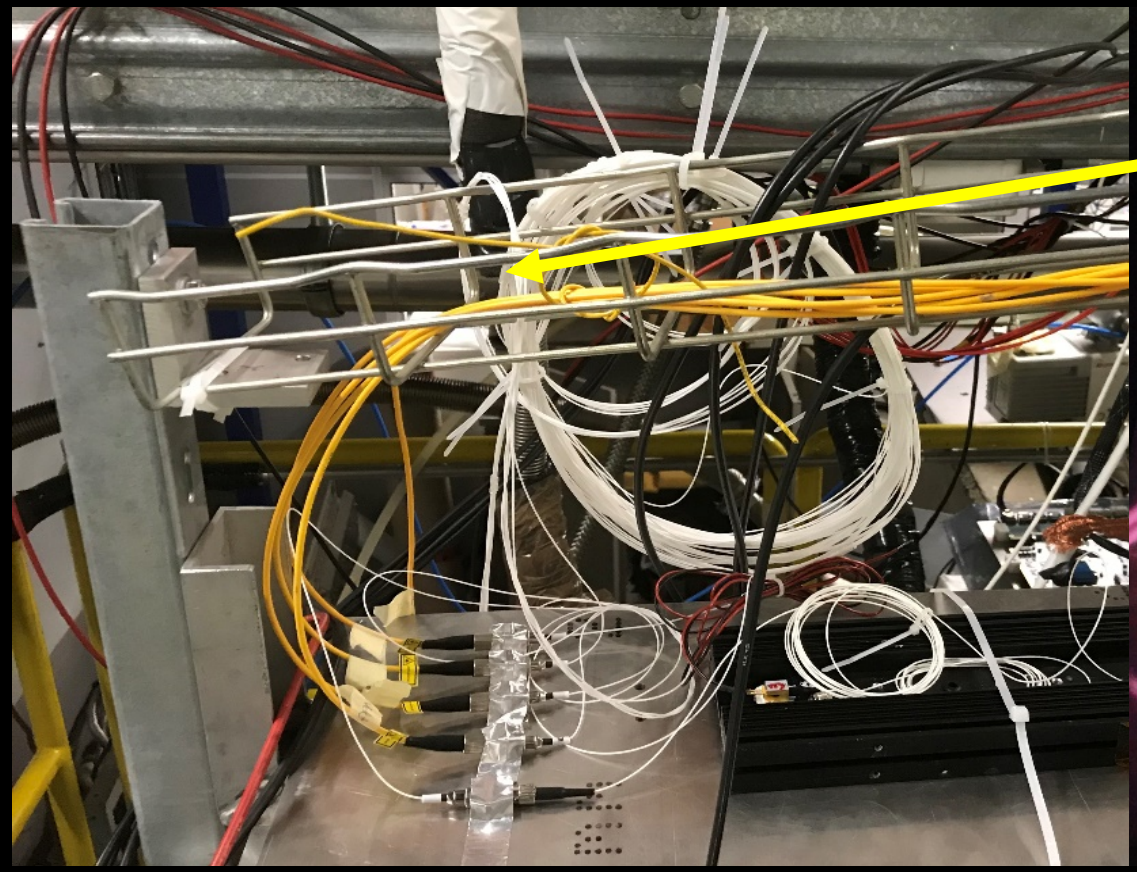


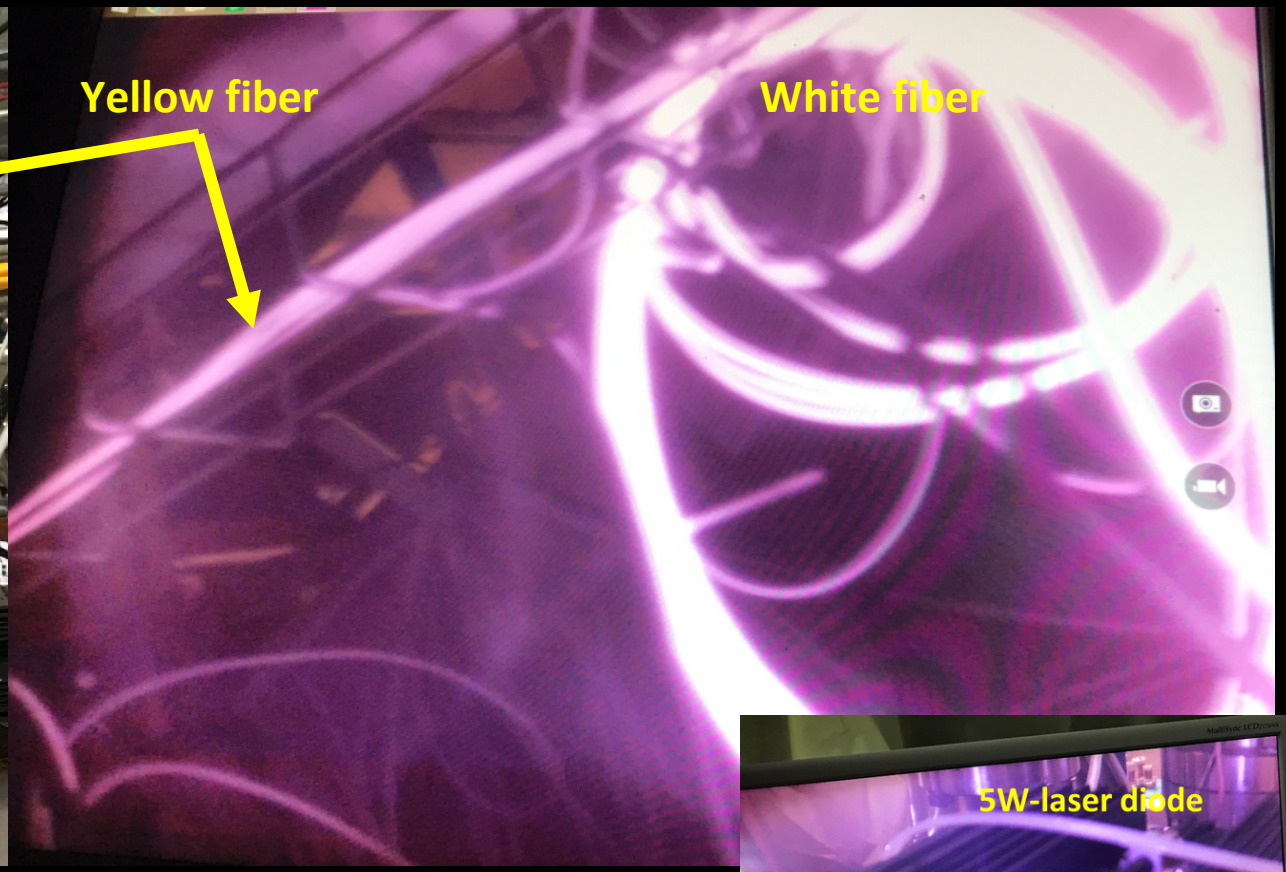


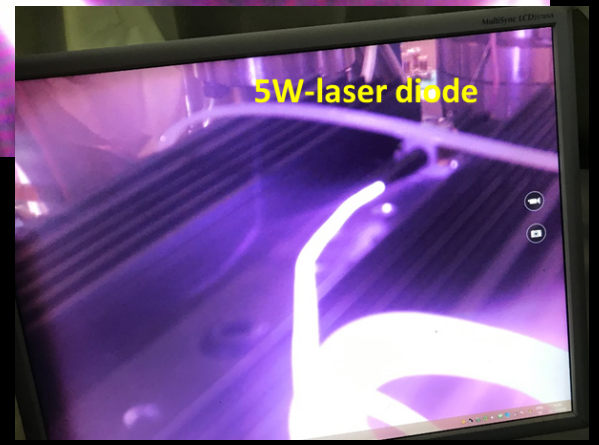
See more photos and movies in: https://cernbox.cern.ch/index.php/s/Cy7jqtf082q0LuH

Light diffusion along yellow and white fibers

Looking with infrared camera







- Here we are looking to ~30 cm yellow fibers and wrapped white fibers
- Laser module emits 976 nm light (E⍰ = 2.04 E-19 Joule)
  for 1W of power we would get ~5 E18 photons.

Summary on 50L tests:

- We have installed three different options:
  [1] Fermilab PoF unit with 4-PPC in series + SiPM board
  [2] Fermilab PoF unit with 1-PPC + 12V-DC-DC circuits + SiPM board
  [3] 5W-laser diode with 5V-DC-DC circuits + SiPM board

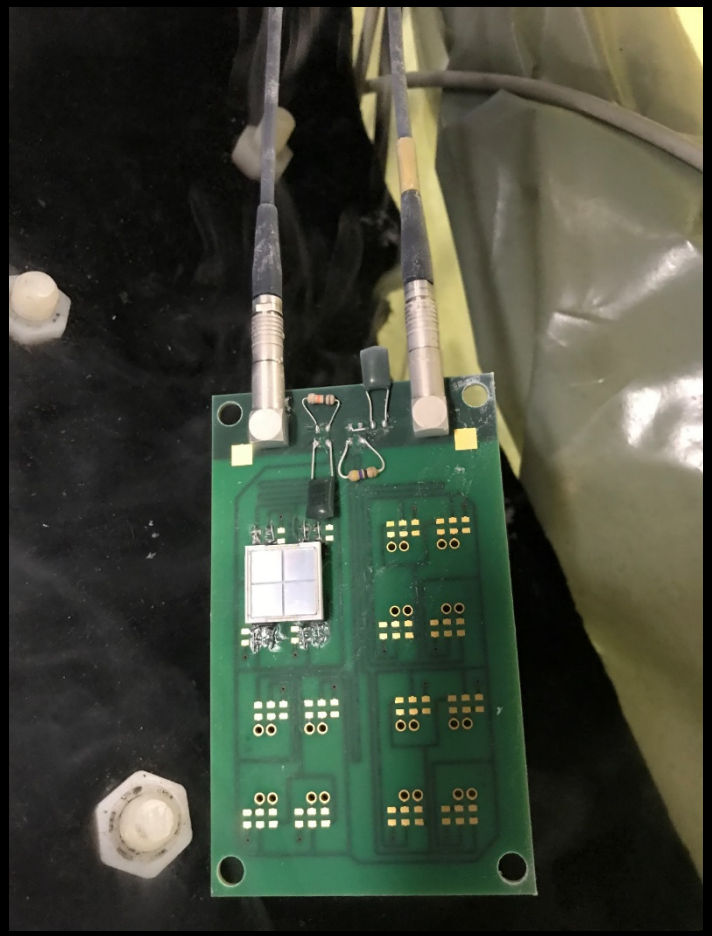
- We get the right voltage output from options [1] and [3], while we do not have enough power for [2]. Observing light diffusing out along the fibers could explain why we could not get right voltage output on [2].

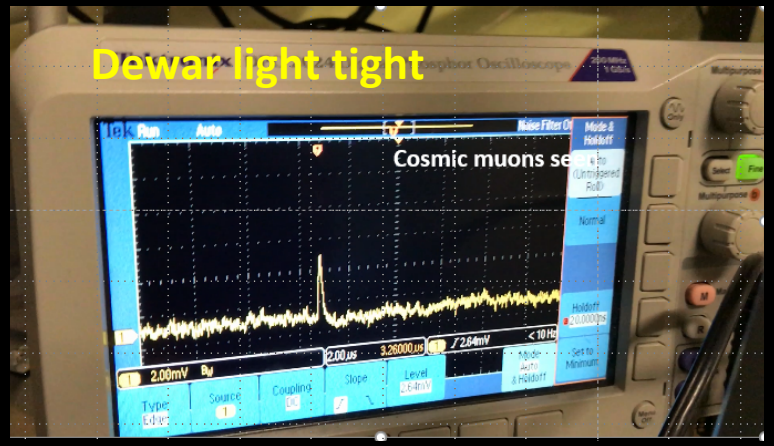
- We could not see argon scintillation light on any SiPM arrays.

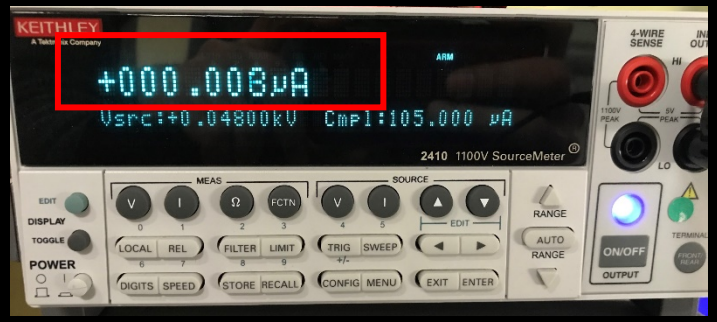
- On option [2] signals from SiPM not seen due to malfunction of signal cable (to be investigated)

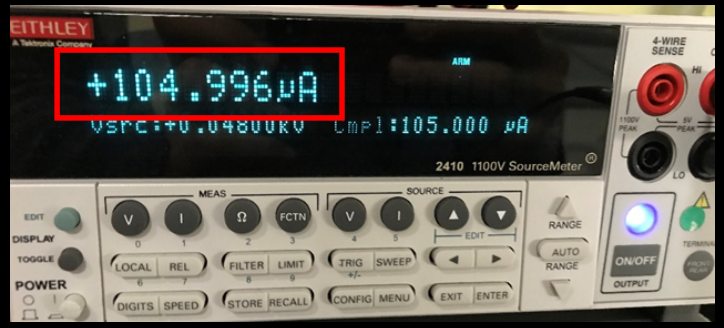
- We do not see any issue on injecting noise from PoF to the charge readout

Quick tests to understand why we could not see any signals on SiPM

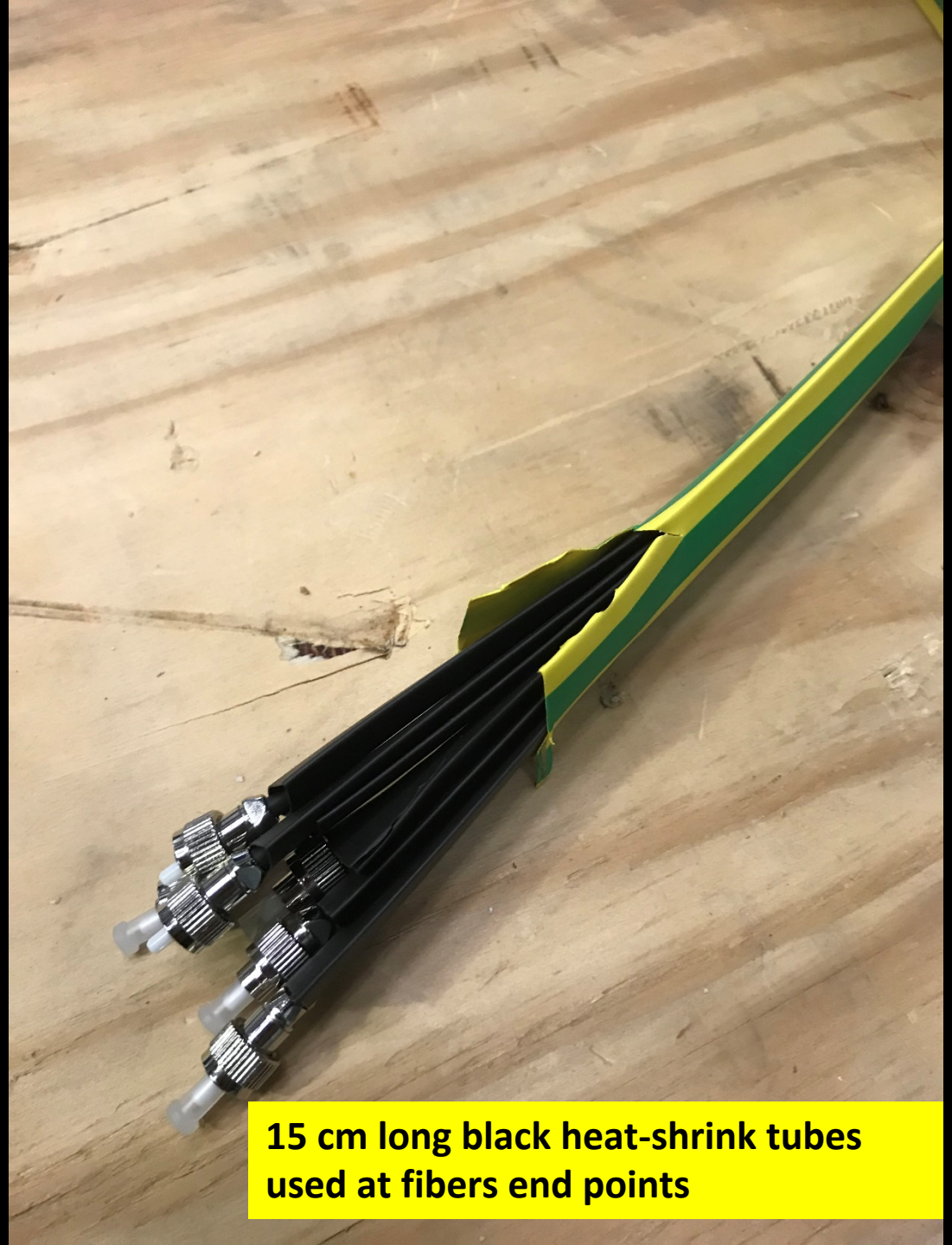








We have used shrink tube to cover the extension fibers



15 cm long black heat-shrink tubes used at fibers end points

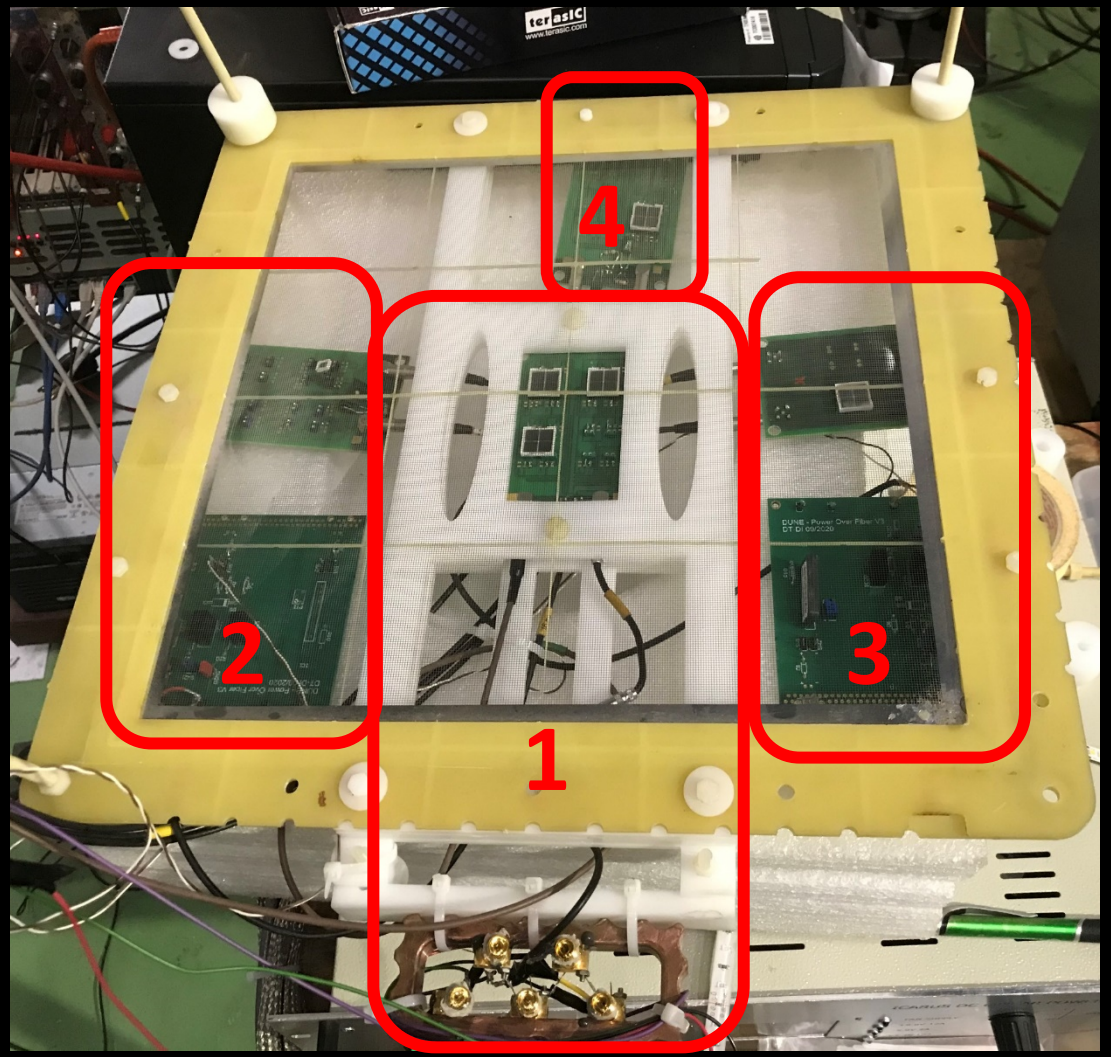
Test setup:

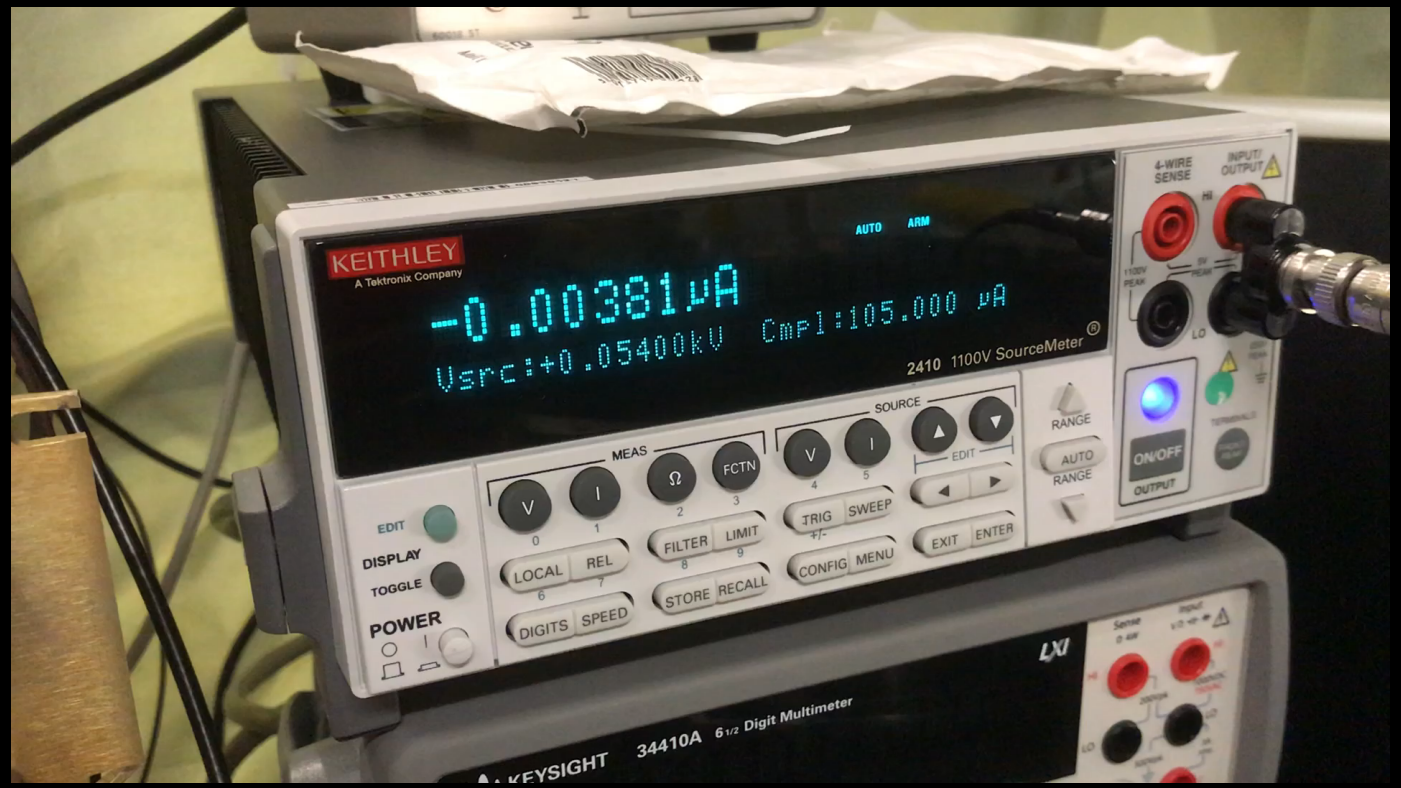
[1] PoF unit option 1, 4-PPC in series provides ~48 Volts voltage input to three VUV-SiPM arrays

[2] PoF unit option 1, 1-PPC provides ~12 Volts input to 12V-DCDC circuits. DCDC provides ~48Volts of output to 3x3 mm2 VUV-SiPM

[3] PoF unit option 2 (either 3W or 5W laser diode) used with 5V-DCDC circuit. DCDC provides ~48Volts of output to VUV-SiPM array

[4] Reference VUV-SiPM array biased with Keithley picoammeter.

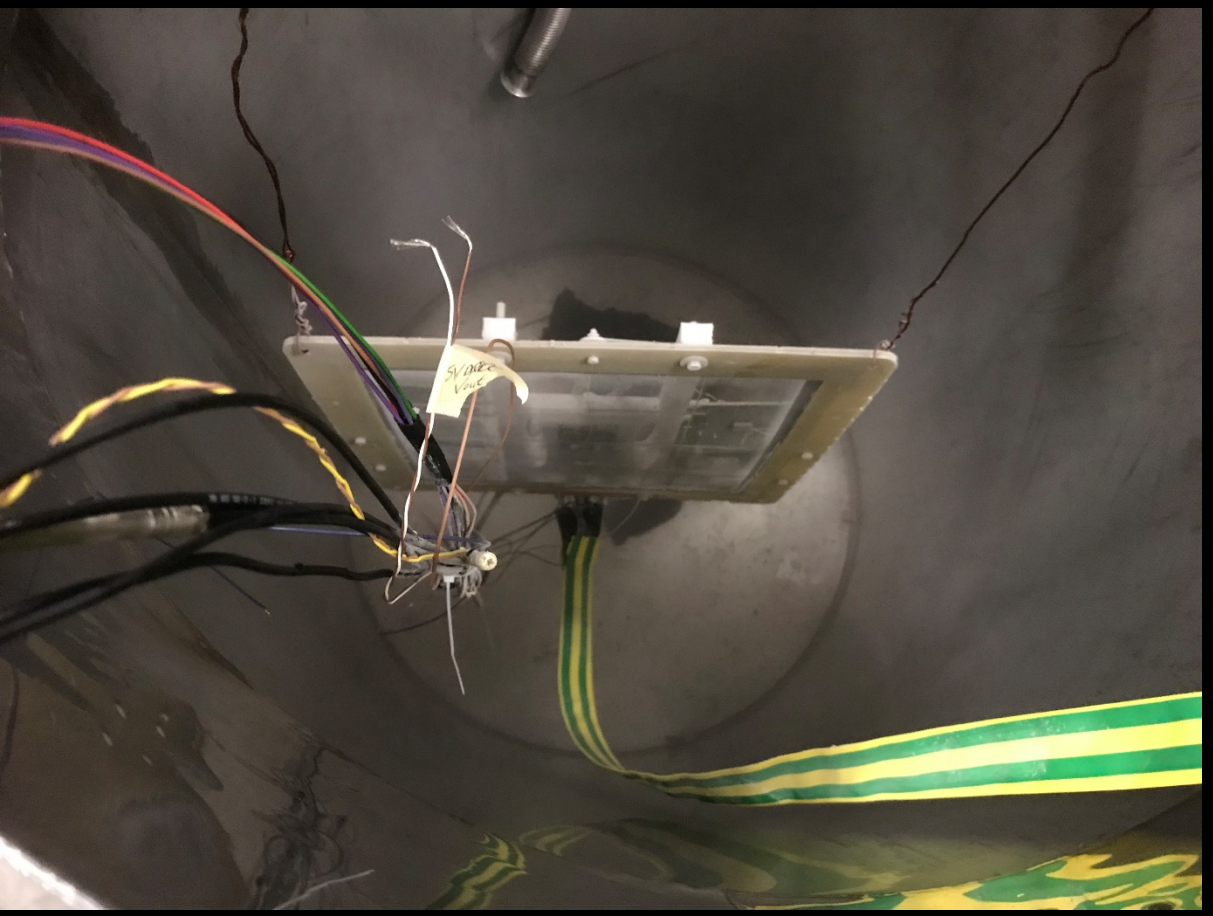


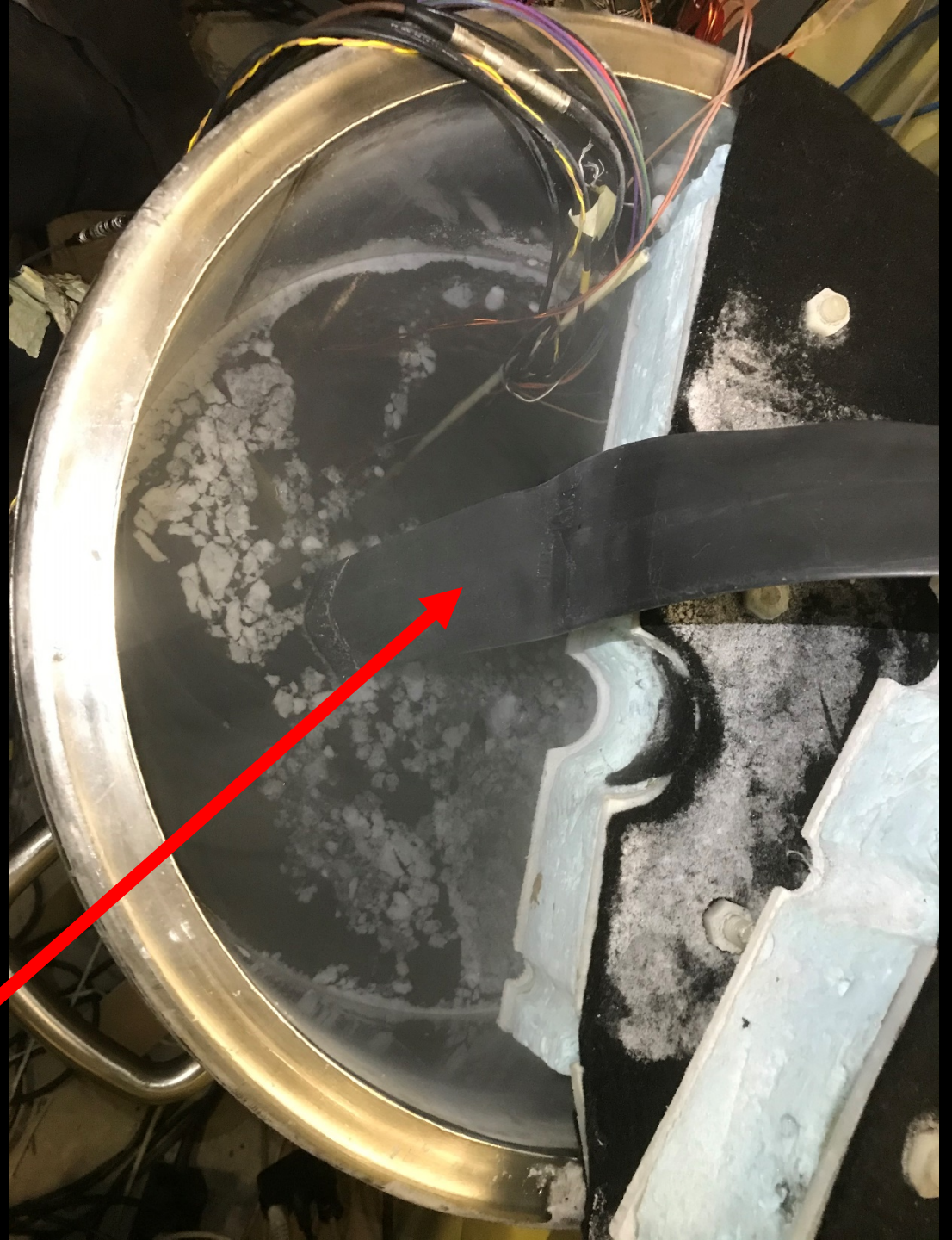


Play the video

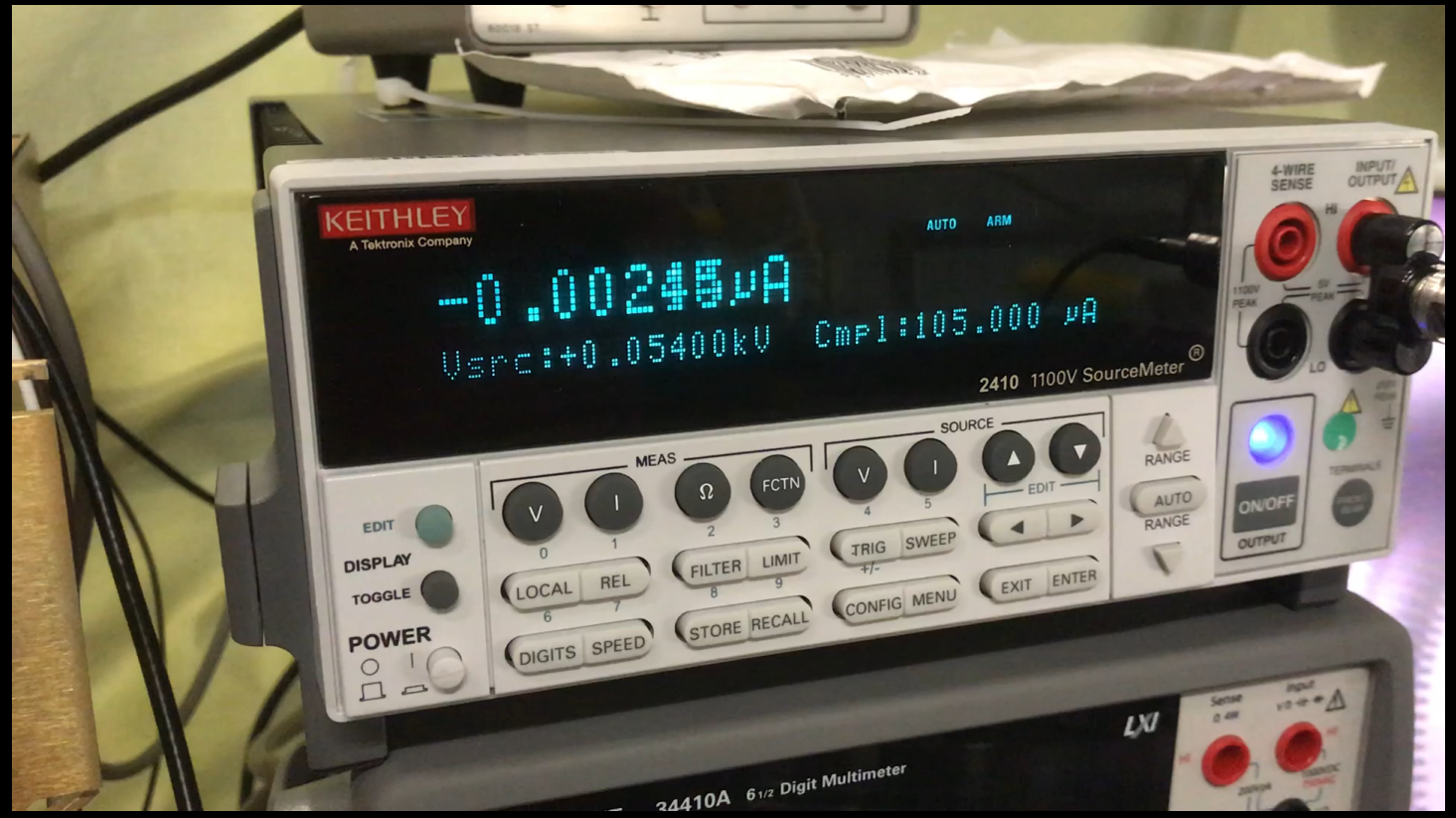
Yellow-green heat-shrink tubes was not good choice!
Light diffused also from the heat-shrink (seen clearly w/ infrared cameras)!

- We have used reference SiPM board powered and current readout w/ Keithley.
- PoF unit OFF, current on Ref_SiPM < 0.01uA
- PoF unit ON, current on Ref_SiPM ~45 uA





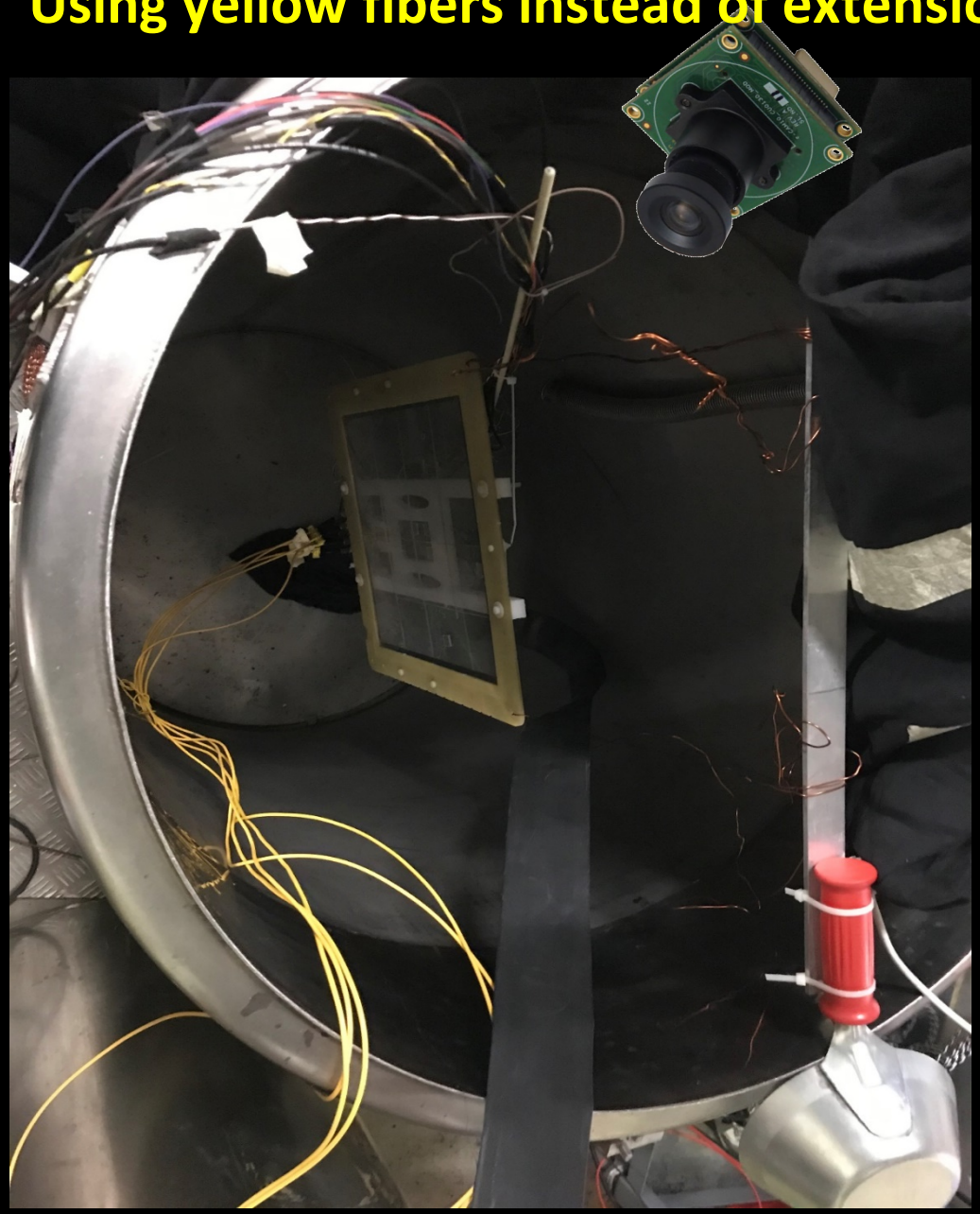
We have inserted yellow-green shrink tube into wider black heat-shrink tubes



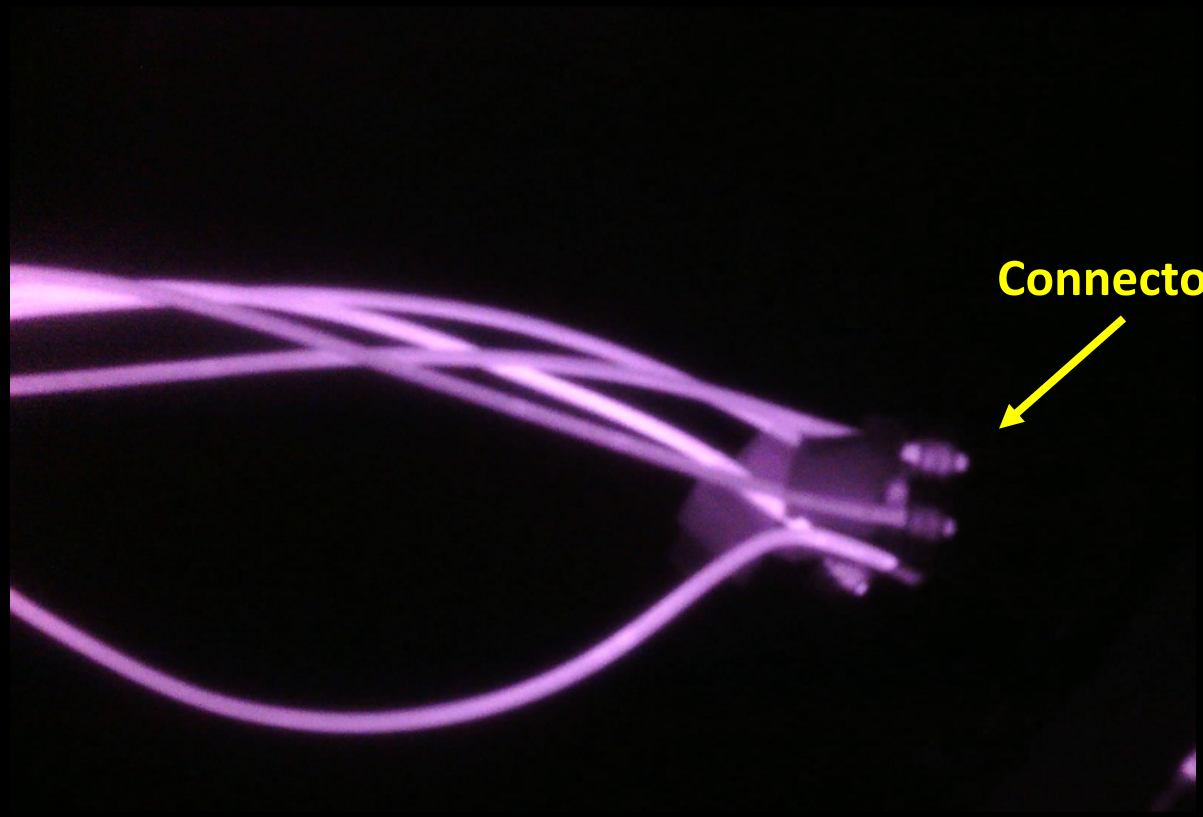
Play the video

- Using black heat-shrink tube on the top of previous tubes improve the situation. Still we have some light diffused into the dewar!
- We could not see the diffused light w/ infrared camera while the impact could be seen on the reference SiPM board.
- Most probably the light is diffused around the PPC connectors.
- PoF unit OFF, current on Ref_SiPM < 0.01uA
- PoF unit ON, current on Ref_SiPM ~0.1 uA
- Cosmic muons seen on SiPM board powered with PoF units (4-PPC in series)

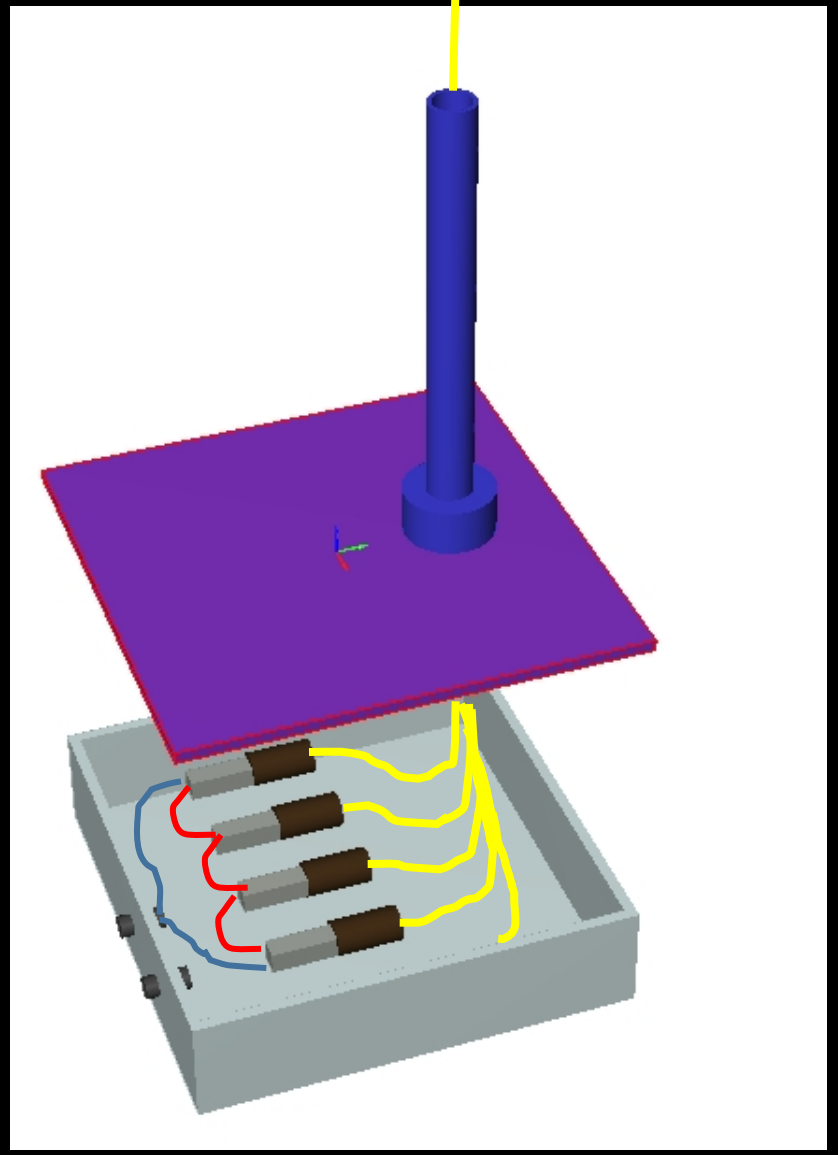
Using yellow fibers instead of extension fibers



Here we use laser power of ~2W
(1.8 kOhm setting resistors)

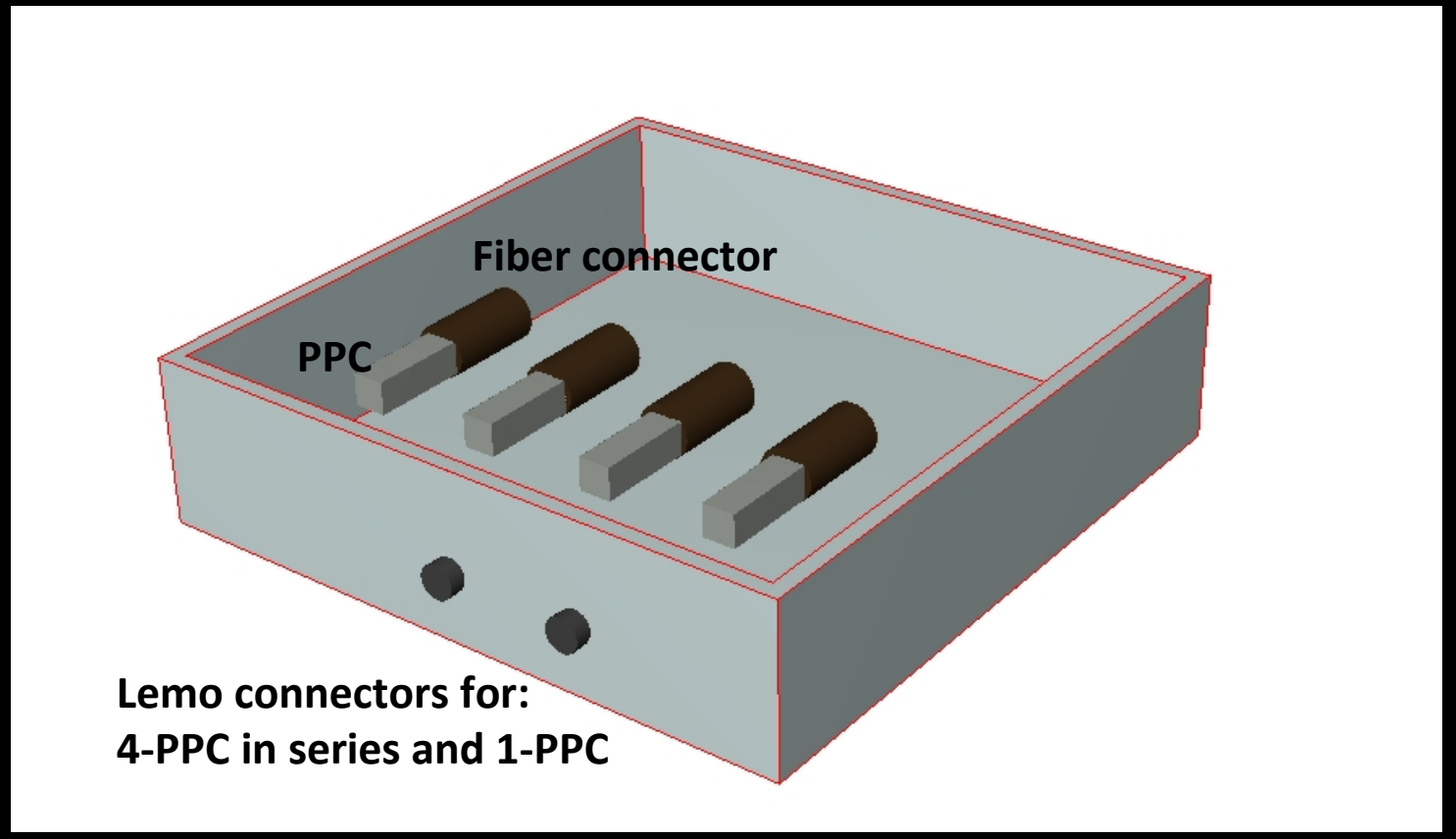


Infrared camera focused on PPCs



Dimensions and box shape to be defined.

An idea to pass the fibers to PPC modules and power to SiPM circuit



Lemo connectors for:
4-PPC in series and 1-PPC

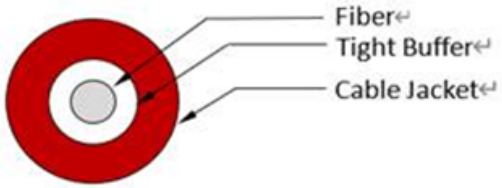
What do we learn from PoF tests?

- We can get ~48Volts of voltage output from both PoF systems
  - Need to study once more again the stability
- Bubbling seems not an issue
- No noise injected into charge readout
- Need to find a good solutions for fibers used inside the cryostat
- It would be nice to use more sophisticated fiber feedthrough (w/ FC-FC connectors).
  - Need to be very careful on handling, moving around w/ the current fiber feedthrough.

What is the next?

- **Prepare the box to host PPC units and isolate diffused light along the fiber**
  - **Xavier has found cryogenic fibers (to be tested)**
- **Test whole system in LAr**
- **Start long stability run in LAr**
- **R&D on transmitting the signal from SiPM board to out of cryostat via PoF technology**
- **..**

backup

			
Part no.		FPC-06227NN-xxx18CC	FPC-06227NN-xxx09CC
Fiber	Numerical Aperture (NA)	0.27	0.27
	Index Profile	GI	GI
	Core Diameter	62.5 ± 2 µm	62.5 ± 2 µm
	Cladding Diameter	125 ± 2 µm	125 ± 2 µm
	Coating Diameter	250 ± 10 µm	250 ± 10 µm
Tight buffered jacket	Material	ETFE	ETFE
	Diameter	0.9 ± 0.05mm	0.9 ± 0.05mm
	Color	White	White
Cable jacket	Material	ETFE	-
	Diameter	1.8 ± 0.1mm	-
	Color	Brown	-
Cable Attenuation		< 3.5dB/km (@980nm)	< 3.5dB/km (@980nm)
Min. Bend Radius (Static)		30mm	30mm
Min. Bend Radius (Dynamic)		40mm	40mm
Weight		4.5g / m	2g / m

YCH-H6424 PPC with Al heatsink

Passive Heatsinking Option:

The YCH-H6424 PPC's performance with a heatsink is illustrated to demonstrate the adaptability of the YCH-H6424 PPC. Custom heatsinking can be easily applied to the YCH-H6424 PPC to generate higher power output, and higher performance. The below summarizes the performance of the YCH-H6424 PPC with a 50 x 24 x 17 mm aluminum (Al) heatsink. An efficiency of ~26% at 10W input is achieved.

Electrical Characteristics of YCH-H6424 PPC with Al heatsink **

Optical Power (mW)	2,000	5,000	10,000
Pmax (mW)	525	1,349	2,600
Vmax (V)	17.7	16.9	16.1
Imax (mA)	29.7	79.7	161.1
Efficiency (%)	26.3%	27.0%	26.0%

*** Typical converter performance with ambient temp of ~25°C*
*** Tested with 975 nm wavelength laser*
*** PPC and Al heatsink held in free space, with no active airflow over the heatsink fins or PPC*

PARAMETER	SYMBOL	VALUE	UNIT
Reverse Voltage	V_r	2.0	V
Operating Temperature	T_{op}	+10~+30	°C
Storage Temperature	T_{stg}	-20~ +80	°C
Lead soldering temperature (10 sec.)	T_{ls}	260	°C

Features:

- 808nm
- 2-Pin Package
- PD Optional
- Aiming Beam Optional
- TEC Cooling Optional

Applications:

- Medical Laser Treatment
- Pumping
- Others

Specifications

	Min.	Type	Max.
Center Wavelength@25℃	±3nm	808nm	±10nm
Spectral Width (FWHM)	----	3nm	----
Output Power	----	2.5W	----
Temperature Coefficient of Wavelength		0.3nm / °C	
Threshold Current (Typ.)		0.3A	0.7A
Operating Current (Typ.)		2.7A	3.0A
Operating Voltage		1.9V	2.3V
Slope Efficiency		1.0W/A	
Fiber Core Diameter	105um(200um 400um Optional)		
Fiber Numerical Aperture	0.22 (0.15 0.37Optional)		
Fiber Length	100cm		
Connector Type	FC (SMA905 Optional)		
Package Style	2-Pin (4-Pin ,9-Pin Optional)		
TEC Cooling	Optional		
Built-in Photodiodes	Optional		