DUNE Calibration and Cryogenic Instrumentation Consortium (CALCI)
Initial Design Review of the Ionisation Laser Calibration system

Question from Committee, Sep. 16

September 16, 2020
V 1.0

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1. Is the mechanical support and the vibration isolation of the laser box sufficient? What are the relevant issues driving this kind of design decision?

The stand is made of steel with a reinforcing strut and with welded construction. The support is very stiff. On the top of the stand is the laser box, bolted rigidly to the support. Any vibration of the support stand by the I-beams will be transmitted to the laser box. The details of the vibration displacement spectrum at the laser box will depend upon the displacement spectrum at the I-beam and on the mechanical transfer function of the stand. We expect vibrations to be small, but there may be frequency bands driven by compressors, transformers, etc. where the amplitude is excessive. These can be mitigated by use of elastomer pads to provide simple damping and (if necessary) more elaborate mechanical filters or pneumatic isolators can be used. Optical tables are often equipped with damping systems, both passive and active. We would consider installation of such measures as necessary upon measurement of the local displacement noise spectrum. (We may have preliminary data from our tilt sensors that may be of use. A specific program to collect such data could be undertaken on the ProtoDUNE-II detector frame.) For now, we can design in such measures at both the connection point to the I-beams and at the top of the stand and laser box.

A related significant problem may be the pointing of the light box laser beam to a periscope mirror. To assess this we must consider that there are two separate frequency domains for any vibrations:

- A low frequency spatial variation between a periscope mirror and a laser box beam. The angular change due to base motion (e.g., a rolling, like a wave) will cause a pointing error and move the light beam. This is expected to be very small, as measured by the flexure of the top of the tank.
- A high frequency vibration would shake the base of the stand but would do little to the laser box. This motion can be damped using the elastomer pad bolted between the I-beams and the base of the stand.

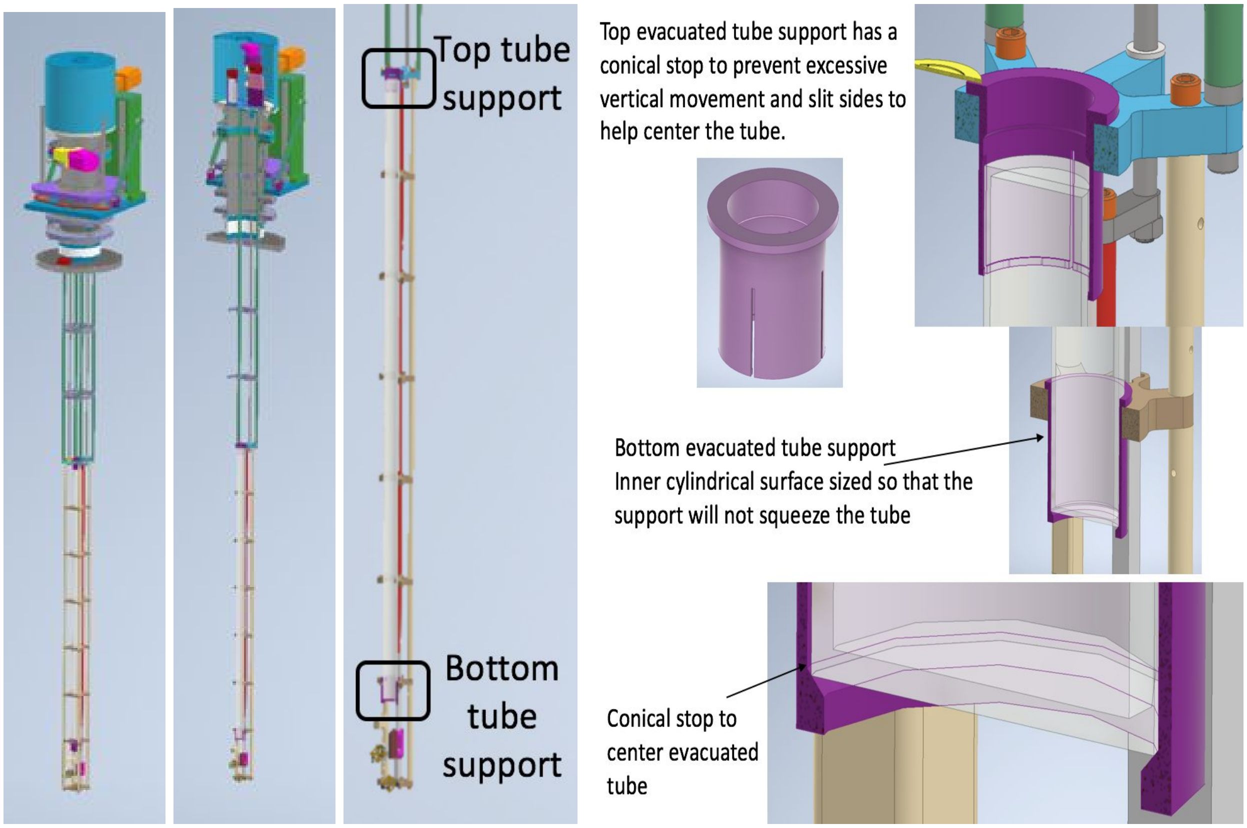
The low frequency vibration across the top of the tank would be of most concern. Taking as an example a 10 m long beam path, a lateral displacement at a periscope mirror of 5 mm would require an angular variation of 0.5 mradian = ~0.03 deg. These considerations may place an upper bound on the optical path length between laser and periscope to avoid long lever arms and how we distribute laser across the cryostat.

Once we have guidance on where we can actually place the stand (both for ProtoDUNE & DUNE), we plan to measure any movement of the support structure and develop concepts to mitigate any problems that we discover as discussed above.

2) What engineering analysis is envisaged going forwards to ensure that the evacuated tube can withstand all of the different cryogenic conditions during cool-down?

The MicroBooNE laser periscope demonstrates that the concept is reasonable as the same tube has been used in MicroBooNE. Additionally in our case, it actually has less stress as it is not held at the flange. We plan to fabricate a lower periscope assembly which will include the evacuated tube. This assembly will be thoroughly tested in a cryogenic environment at LANL.

As can be seen in the pictures below, the glass tube is very gently supported and it is allowed to move (about 0.5 mm or so). The Maroon object is the support structure present at the top and bottom of the tube and it is a conical stop that will help center the tube. The bottom support is designed such that it will shrink with temperature and doesn't squeeze the glass tube.



Top evacuated tube support has a conical stop to prevent excessive vertical movement and slit sides to help center the tube.

Bottom evacuated tube support Inner cylindrical surface sized so that the support will not squeeze the tube

Conical stop to center evacuated tube

Figure 1: Evacuated glass tube support structure and description

3) Is the connection between the top and bottom sections of the periscope adjustable / re-alignable after installation?

It is not adjustable. The two sections are fixed together with screws as one system, there's no mechanical alignment at that step. We have the port aligner that provides one-off adjustment for the straightness of the periscope as a whole. On the other hand, if the worry is about the beam alignment this is actually carried out by adjusting the position of the warm mirror(s) on top of the bucket which can be done at any time. The alignment target (with the visible laser) and the LBLS system (with the UV laser) allow alignments to be corrected (if needed) during the life of the experiment.

4) With such a long structure inserted into the cryostat with supported only at the top, is the periscope rigid enough given effects such as the temperature gradient and liquid argon movement? What kind of scenarios are taken into account for the mechanical analysis of the stability of the system?

Part of the reason we went to stainless steel instead of Torlon (as in the case of MicroBooNE) on the chimney side is to give the rigidity needed for the structure. In addition, we don't think the liquid argon flow is strong at the top compared to the bottom. The lower part of the periscope is very similar to MicroBooNE and PEEK and Torlon are not very different. MicroBooNE is a proof of principle for this. However, we do plan to test the response of PEEK in LAr at LANL as part of our QA/QC plans. The periscope as a whole will be extensively tested using a large bucket dewar. As shown in Figure 2 below, the idea is to test in an environment that is very similar to the installation in the real experiment.

Figure 2: Planned periscope test in a large LAr dewar at LANL as part of QA/QC

5) Welding the view-ports will introduce stress to the windows as well (compared to the standard gasket and bolts solution). welded view-ports cannot be replaced if they break. Typically view-ports developed for vacuum applications do not withstand much positive pressure. Are these considerations taken into account in the design? Should these view-ports be custom made?

These view ports are commercial (MDC – Insulator Seal) and are rated for Ultra High Vacuum (UHV) service. We can contact MDC and confirm that the chosen view ports are strong enough to deal with a ~5 psi over pressure (nominal operation 1.9 psi, maximum due to accidental loading 5 psi).

What is the advantage of welding the view-ports directly to the main flange?

Guaranteed to seal and obey the 10-8 mbar/l/s requirement. We're open to discussing this, but thought that with elastomer o-rings, the seal would not be as good.

6) What's the plan going forward for optimising the end-wall system?

After clarification with Filippo, we answer for different aspects:

- Choice of eccentric axis offset. This is chosen to be 30 mm, no uncertainty here. The initial design planned for 40 mm, but due to interference of the various parts -- periscope, rotary stage -- it would imply either a larger, custom, rotary stage (RNN1000) or reducing the size of the periscope structure (compromise on stability). We decided against those options, and settled on a smaller offset of 30 mm, that still provides a very significant improvement on coverage for the end-wall beams.
- Alignment of beams. The alignment is trickier here because every time we rotate the lower stage (not very often, though, just a few times per scan), the axis is tilted. During the installation phase we will have to make a careful verification of the alignment (using the visible laser, the targets and the cameras) for various positions of the rotary stage, and choose top mirror positions that are good for all of them. The basic design of the system was shown in page 22 of the Laser periscopes talk. We can think of possible improvements to this, as adding additional degrees of freedom (XY positioning) to the mirrors and/or remotely operated adjustments. These would require a somewhat larger mirror box on top of the bracket, but that should be easily accommodated.
- Choice of the electrical break. For ProtoDUNE, we will use a commercial break made by MDC. They sell weldable ceramic breaks, but also the same breaks welded by them to standard flanges. The bottom flange is in any case a 250CF that connects to the calibration port. We have quotes from them (MDC) for a medium break welded to a top flange with an inner diameter similar to the Thermionics RNN600 rotary stage (the one we'll use in the Top FC design). For the end-wall the inner diameter needs to be bigger. We already have a quote for custom piece from MDC for 230 mm, that we asked when we were still considering the RNN1000 rotary stage. In the meantime, for cost and schedule reasons, we decided to use the smaller rotary stage RNN800 (and correspondingly reduce the eccentricity offset from 40 mm to 30 mm), but we do not have the corresponding MDC quote for that yet. Since it's smaller than another quote they already made for us, we're confident we can have it shortly.
- Alternative electrical break. If we could produce in-house an electrical break made with standard steel flanges and glued POM pieces, this could signify a cost saving. It will require proof that the POM/steel bond (not trivial) is leak-tight enough, so that may be classified at this point as an R&D project (at LIP). It is not our option for ProtoDUNE, unless very good and solid results arrive in the next couple of months. But it could be an option for DUNE where, due to the larger number of periscopes, it makes more sense to consider cost-saving options. And in the meantime, the need for the breaks themselves might be clarified.
- Optimization of the positions mentioned in page 29 of the Laser periscope talk. That optimization can be done via software with the same code used so far. And it's not a priority since the system can position the mirror anywhere within the 3 cm radius circumference.

7) Was the FEA for the field distortion done with the bottom section of the periscope made out of PEEK?

Bo performed these simulations for us.

Response from Bo: “The simulation assumed the periscope is a perfect insulator and its outer surfaces are fully charged up (no normal E field component). The material used doesn’t matter.”

8) Considering that the ceramic insulation needs to support more than 130 kg with a long lever arm, what mechanical analysis has been performed to show that it has adequate strength?

This is a very good question and something we have been thinking about on how to address. Candidate Scheme to combine the functions of the vacuum break with the port aligner is shown in Figure 3 below. This approach results in the load path avoiding the ceramic break.

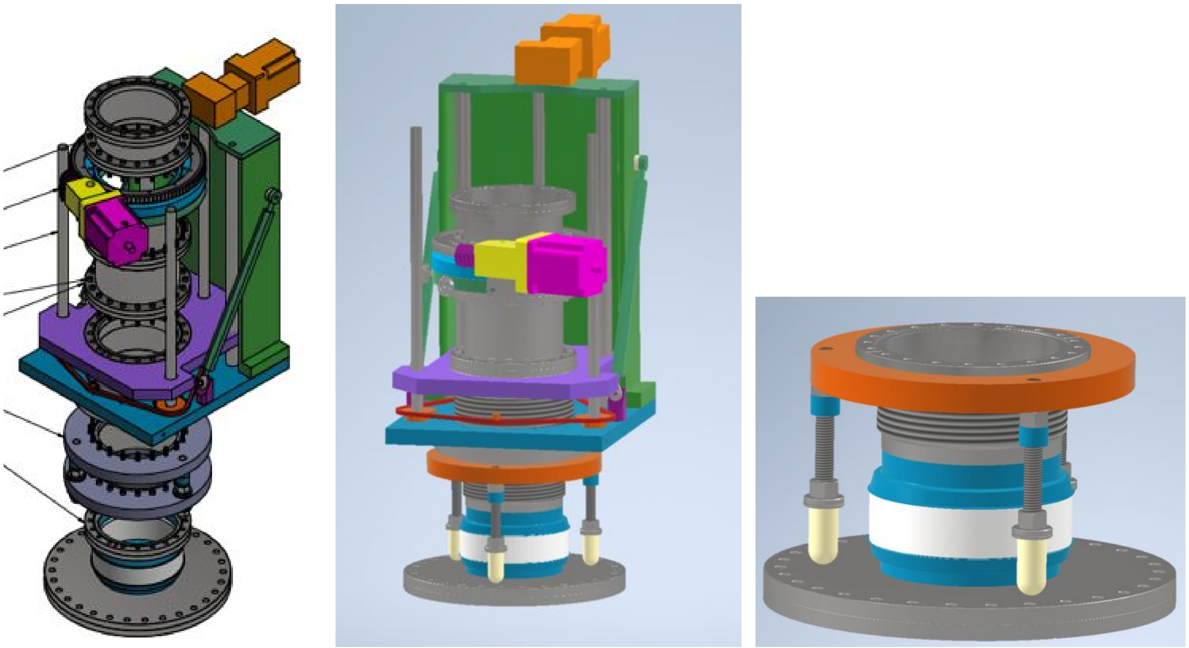


Figure 3: (Left) original concept, (middle) Candidate scheme to mitigate load on the break, (right) close up view of the candidate scheme

9) Is there adequate protection in place to prevent injuries from moving parts of the system?

Not yet designed but we certainly can if this is determined as an issue. This problem can be solved using nested safety shields.

10) Isn't 60 mJ/pulse direct on PiN too much? Any tests made or planned on this?

While the maximum laser power per pulse is 60 mJ, this power is spread over the 6 mm diameter of the beam and only the central 1 mm diameter is injected in the periscope as the beam will be collimated through an Iris in the laser box. It should be noted that the beam power is not spread evenly over the beam spot , but has Gaussian shape. By the time the laser beam reaches the pin diode at a distance of about 10 m, it is about 5 mm in diameter while the pin diode photosensitive area is 2.2 x 2.2 mm^2.

Rough calculation shows that the beam power will be less than a couple of mJ by the time it hits the pin diode.

In the LBLS pin diode testing document (section 3), there is a description of the plan to measure the maximum laser power that will not induce damage to pin diodes. For this purpose, pin diodes will be placed in a dewar filled with liquid nitrogen and illuminated by the 266 nm light from the NdYag laser at UH. The laser power will be assessed with a power meter.

We also plan to test pin diodes in the integration test with the laser periscope at LANL.

Based on the results of these tests, we will attenuate the laser power using the attenuator as needed in ProtoDUNE.

11) Are there documented details on the PMT / Camera system? They should be included in the system diagrams.

Glenn' talk on cameras at the May 20 CALCI scope review provides more details on the PMT/Camera system.

We have a drawing for the camera and PMT assembly on EDMS.

Vendor choices are still being finalized especially for the PMT. Our first order choices are shown in Figure 4.

For the PMT, the plan is to have a TPB-coated PMT that could see UV light in the bandpass of the periscope mirrors. We currently have Hamamatsu PMT R580 in the design but the exact details and requirements for this need to be flushed out.

For the camera, we are now considering the Astronomy imaging camera, ASI178 MM/MC high resolution imaging from Planetary cameras ($349). These cameras are not very expensive, so we plan to buy a couple of candidate cameras and test them.

Once vendor choices are finalized, the designs will be updated and this change will be straightforward.

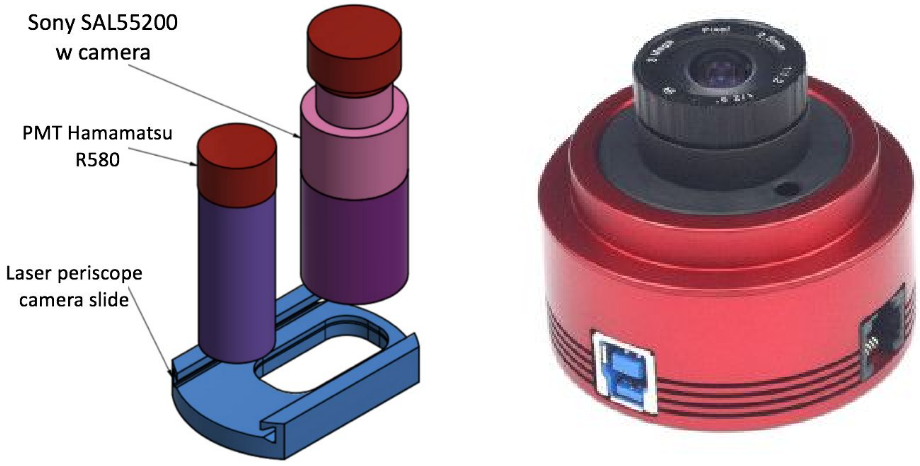


*Figure 4: (left) camera and PMT assembly mechanical drawings (currently in the design). (right) candidate camera from Planetary Cameras with 1/1.8" CMOS IMX178 sensor and a resolution of 6.4 Mega Pixels 3096*2080*

12) Has the MicroBooNE experience been used to estimate the amount of work involved in the project and compared it to the resources presently available?

Yes, the MicroBooNE experience has been useful in this regard. From our understanding the uB effort involved two PIs with significant time commitment, a mechanical engineer, a postdoc, and a student or two. (Igor should correct us if we got this wrong). In the case of MicroBooNE, there were two systems with the same design. In our case, our effort has started with DUNE FD in mind, so the group is comparatively larger as we started and distributed across institutes. Roughly 15 members with varying time commitments across 5 institutes. We have listed the members and their FTE below.

For the ProtoDUNE effort for two laser systems and two LBLS systems, with the commitment and effort listed below, we think we have the critical mass needed to carry out the effort. And we hope to grow and attract more resources/personnel to this effort as we move towards DUNE where there will be multiple systems and will be a substantially significant effort compared to uB or ProtoDUNE.

LANL:

S. Gollapinni (scientist, PI): 0.65
E. Guardincerri (scientist): 0.13
M. Fani (PD): 1.00
J. Boissevain (eng.): 0.50
V. Sandberg (scientist): 0.40
E. Renner (student Eng.): 0.30

LIP:

J. Maneira (scientist; PI): 0.65
R. Alves (eng.): 0.30
N. Barros (scientist): 0.50
V. Solovov (scientist): 0.20
F. Neves (scientist): 0.15
F. Barao (faculty): 0.10 (from 2021 on)

Hawaii:

J. Maricic (PI): 0.40
R. Dharmapalan (postdoc): 1.00
A. Dvornikov (graduate student): 1.00

KSU:

G. Horton-Smith (PI): 0.10

Fermilab:

S. Chappa (senior elec. eng.): 0.10
A. Ghosh (junior elec. eng.): 0.10

Are there particular aspects of the project that are of concern?

We have interfaces with multiple systems (HV, DAQ, facility, electrical, grounding etc.) making integration a significant effort for us. We could really use more active support on this from the technical coordination team (we are thankful for all their support so far) especially because we are working to address issues both at ProtoDUNE and DUNE and the challenges vary between the two. Given the very tight timeline for ProtoDUNE, we can certainly benefit from more support on CERN integration aspects and especially safety requirements and guidance on implementation.