LILAr

*Light Imaging with Liquid Argon

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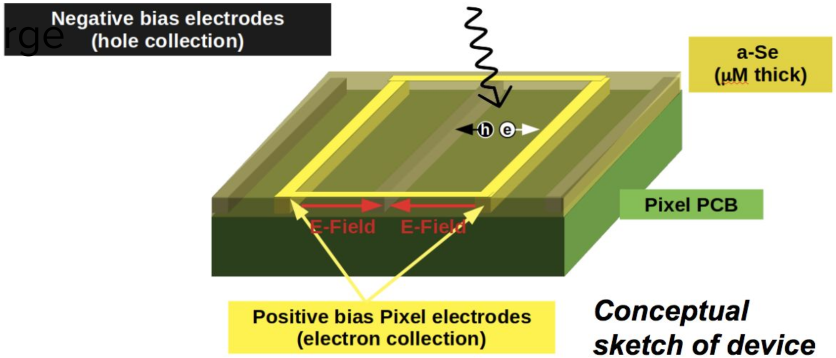
Wider Context: Multiple Modality Pixels

Developing a pixel that can detect both light and charge in LAr.

Strategy: coating pixels for charge readout with photo-conducting material sensitive to UV light.

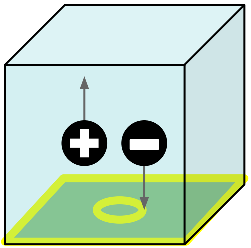
Step 1: develop the photo-conducting material. Exploring different thin-film photo-conductors which may offer an opportunity. The starting point is characterizing amorphous Selenium’s properties: commonly used in X-Ray digital radiography devices, never tested in cryo.



Conceptual sketch of device

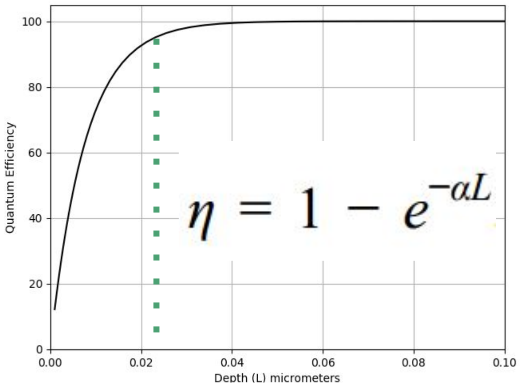
LILAr: LDRD Material Development and Characterization for Light Detection

Why is A-Se interesting?



Assume you can apply a uniform electric field on a block of a-Se some micrometers thick where the electron-hole pair is being created.

To figure out the charge produced, you need to know how thick a layer of amorphous selenium will give you a high QE for the single photon of the right energy ➜ Absorption coefficient!



$$\eta = 1 - e^{-\alpha L}$$

The literature on amorphous selenium reports an attenuation coefficient $\alpha \sim 130\ \mu m^{-1}$ for photons at 128 nm, resulting in a **QE than 99% for thin coatings (> 1 μm) .**

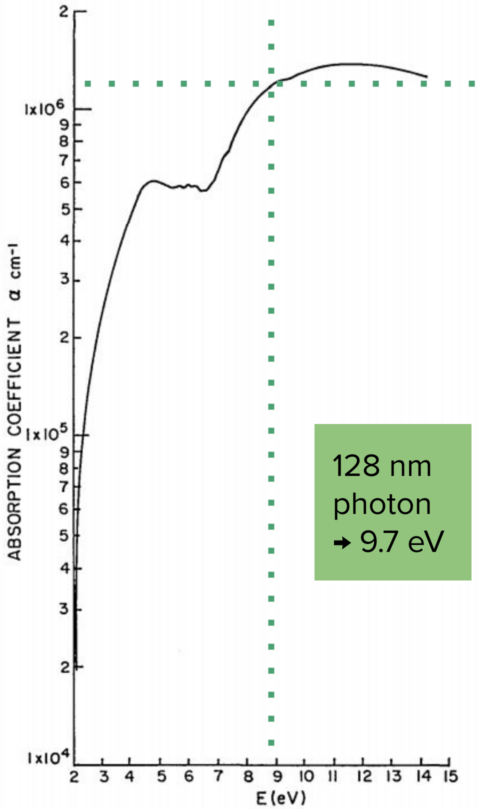


FIG. 6. The spectral dependence of the absorption coefficient, α, of amorphous selenium.

What about the signal? Estimate summary

The amount of charge deposited into the a-Se is given by → $\Delta Q = q \frac{\Delta E}{W_{\pm}}$,
where q is the fundamental charge of the electron, and $W_{\pm}$ is a property of the mobility of A-Se which depends on the electric field and (favorably) on the temperature ($W_{\pm}$ = 7.07 eV). ΔE is the amount of energy absorbed. In a single 4mm by 4 mm pixel, a reasonable assumption for ΔE is 26.46 eV... You start with ~ 3 photons per pixel at 9.7eV / photon and 0.9 QE.

So, transport in the A-Se ΔQ ~ 26.36/7.07 which means that:
3 photons coming in and 3.7 electrons going out.

At the theoretical breakdown voltage of a-Se (~ 90 Volts/μm)
for 100 μm thick deposition ➜ gain factor up to ~1.5 10^3:
~ 4000 electrons for three 128nm photons on a 4mm pixel pad.

These numbers would be very consistent with the current Q-Pix design choice of being between 0.3 and 1 fC (1800 and 6000 electrons) for a RTD (Reset Time Difference).

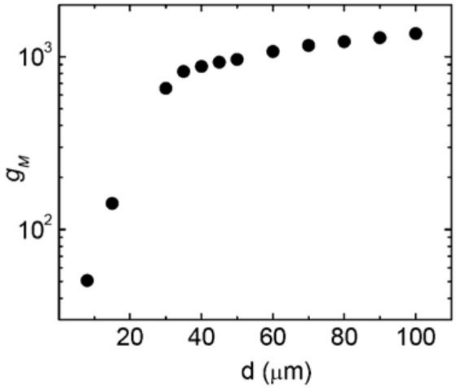


Figure 10 Maximal achievable multiplication gain for different a-Se layer thicknesses.

Two main challenges* granted that you have a signal

Can we lower the breakdown voltage?

Can we read the signal w/ Qpix?

Two main challenges* granted that you have a signal

Can we lower the breakdown voltage?

Material simulation

Material production

Experimental feedback

Can we read the signal w/ Qpix?

Experimental signal characterization at test stand

Modeling of A-Se to understand optical properties w/ VUV light

Professor Muhammad Huda at UTA (condensed matter theorist) has started an A-Se model to better understand and predict the A-Se optical-electronic properties when exposed to 128 nm photons.

The basic approach is Generalized Gradient Approximations in Density Functional Theory, w/ incremental approximations to capture experimentally measured properties via phenomenological models. A promising way to reduce the breakdown voltage is the use of dopands, whose effects can be studied within the constructed model.

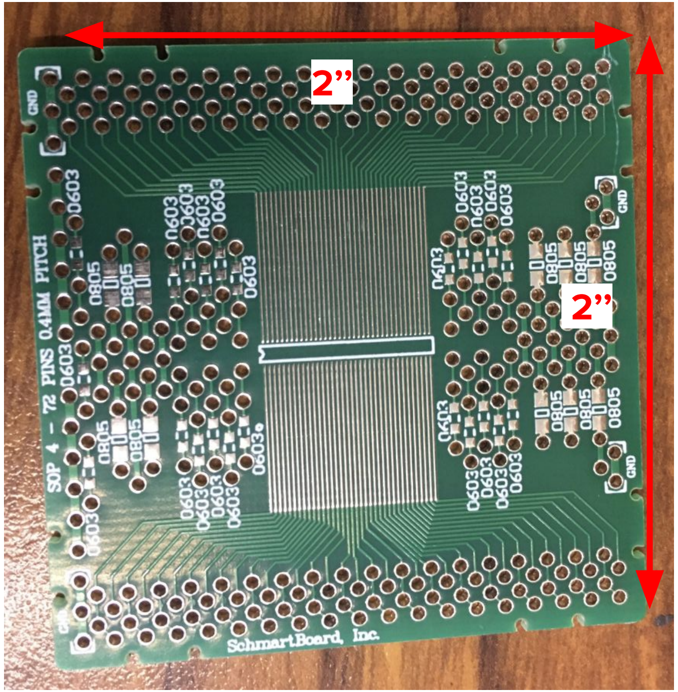
A first, crude version of the simulation show a qualitative agreement for the VUV energy region between old data... off to a good start, but... we need more experimental data!

LILAr

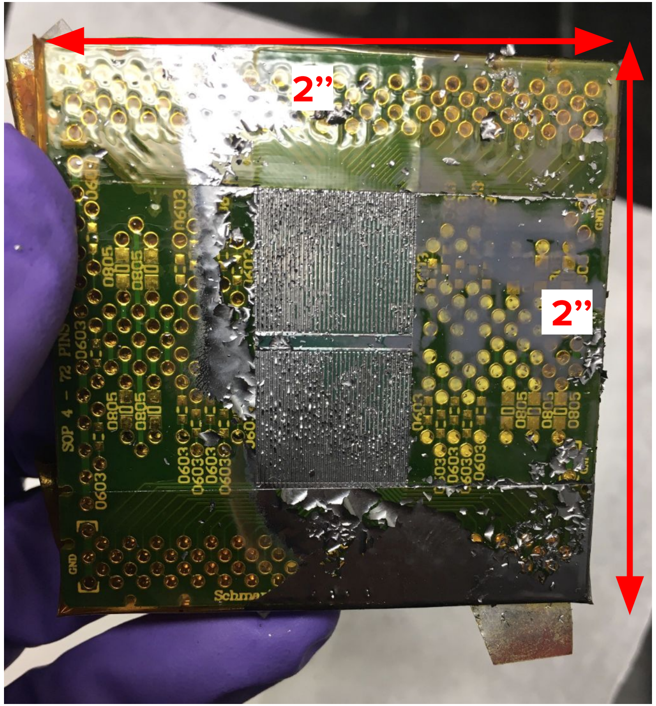
First Prototypes

Commercially available boards.

Coating @ UTA, tests at FNAL.



Schmartboard 202-0008-01
.4mm Pitch (signal gauged together)



First coating attempt **@UTA**
A. Raymond & J. Asaadi

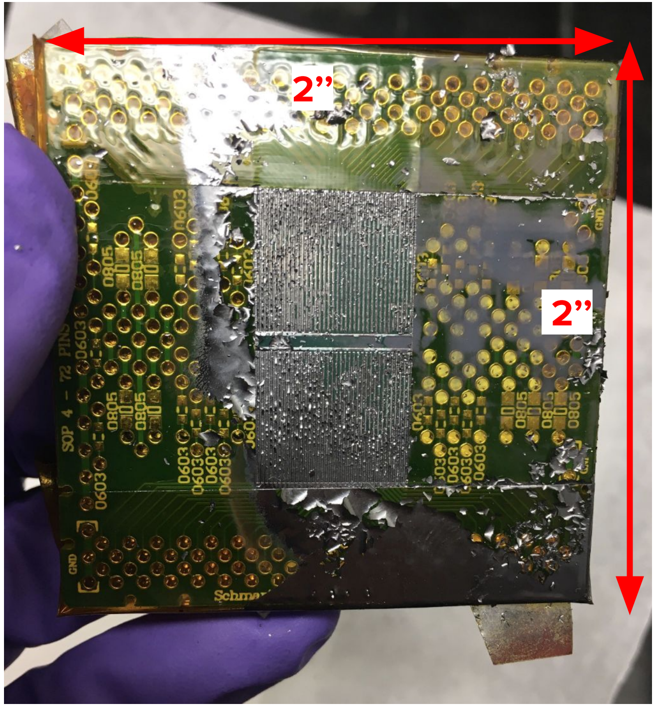
Tests of Prototypes & Material

a) **Basic usability in LAr (FNAL → PAB → LUKE):**

- coating's long term durability
- argon purity

b) Photo Emission Characterization (PAB → theRocket & TallBo). Same battery of tests both in vacuum & cold of each prototype:

- Dark current,
- I-V curves at fixed source distance and intensity,
- Current dependence on:
    - source distance,
    - intensity
    - incident angle of exposure at operating voltage,
- Q.E.



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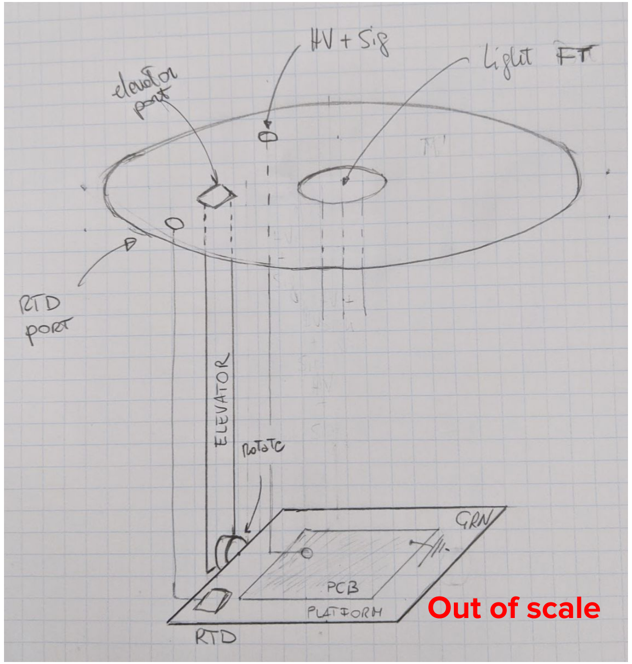
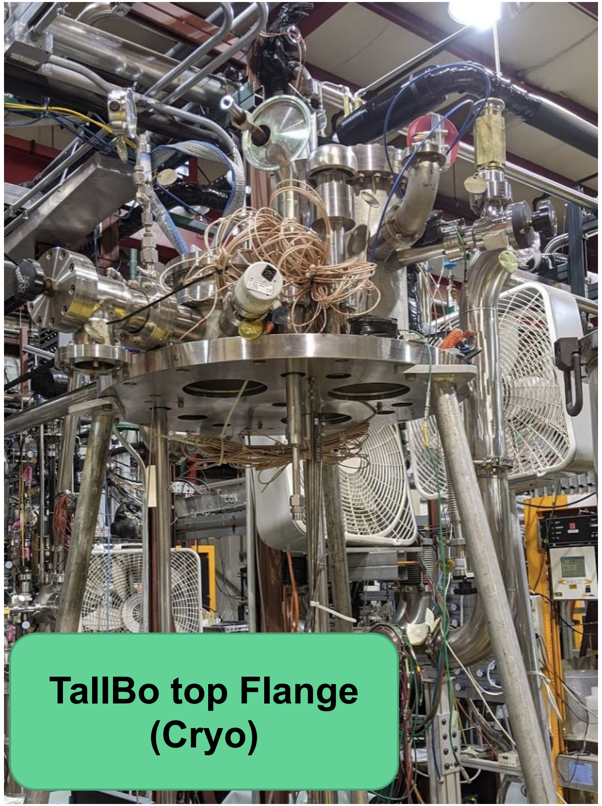
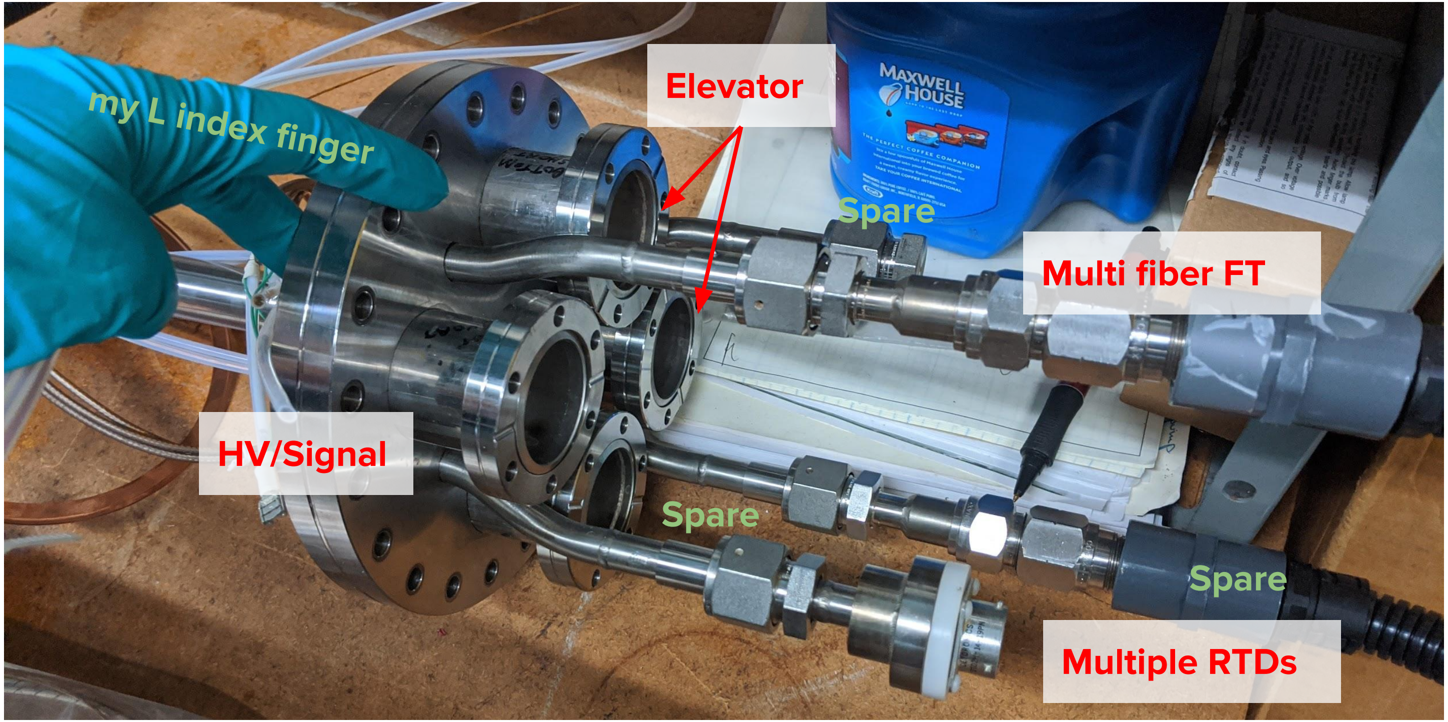
Concept Setup and Vessels

Design one port for both the vacuum vessel and TallBo.





Flange Design



Already available. Vacuum needs to be tested, since it's "borrowed" and repurposed.

It looks fine at a visual inspection.

??? Timeline ???

Illinois is extending shelter in place until the end of April: PAB (our home) is closed.

Before PAB opens:

- Elevator Design & Parts Order (before May 1st).
- Part arrivals: some time after we order them.
- Readout & HV design.

After PAB opens:

- Vacuum test of the top flange (if not successful, order flange) ~ 1 day
- Parts assembly in vacuum and mobility tests < 1 week
- Lab approval [ORC ~ 1 week]
- First tests hopefully within a month of PAB opening!*
- TallBo schedule is up in the air, since there are other “customers”

* when... depends on the COVID19 in both IL and TX.

Thank you!

Readout

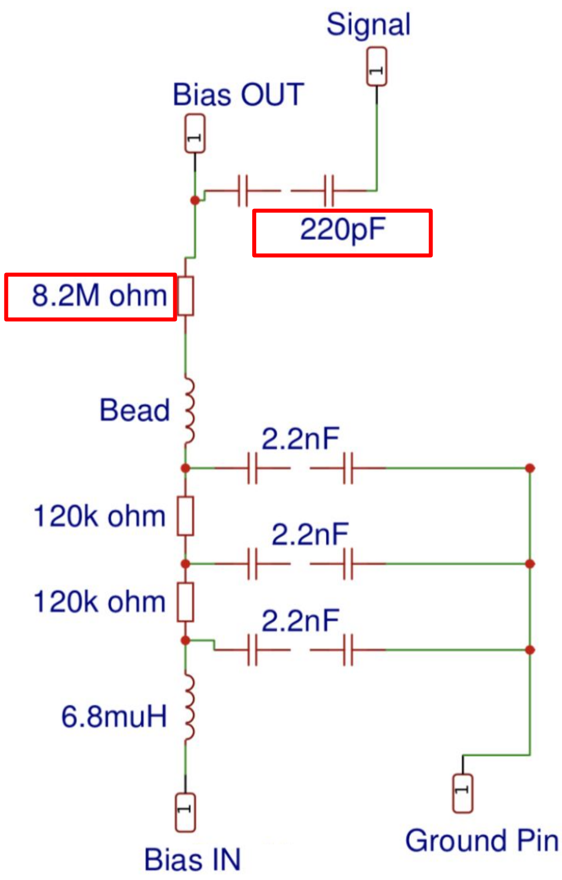
Simple setup

(purity monitor inspired)

Thanks Austin!

Red boxes needs

Changing for sure.



Bias OUT

Bias IN