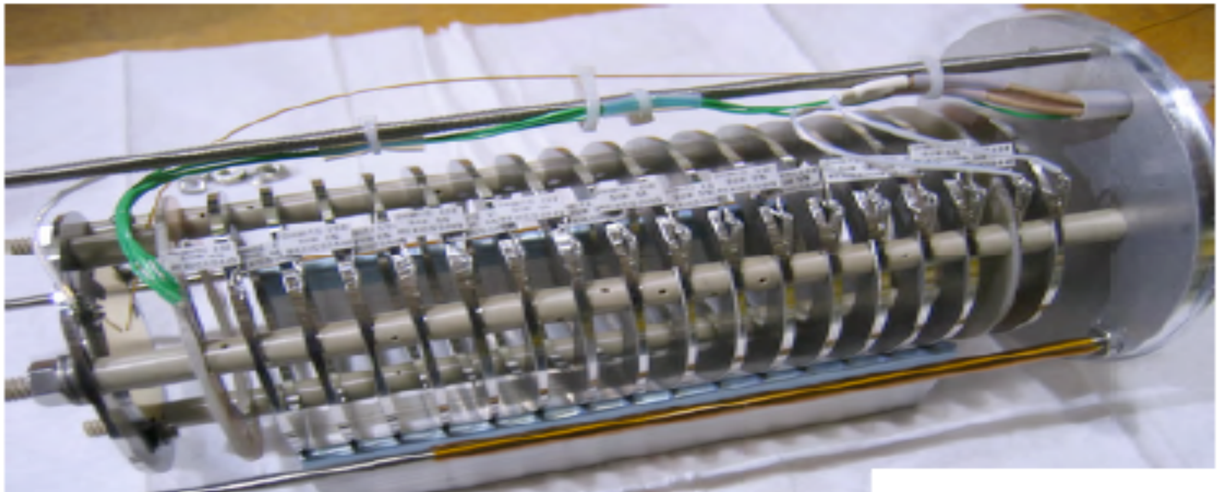


ICARUS clone made at FNAL
(S. Pordes - FNAL May 13th 2006)

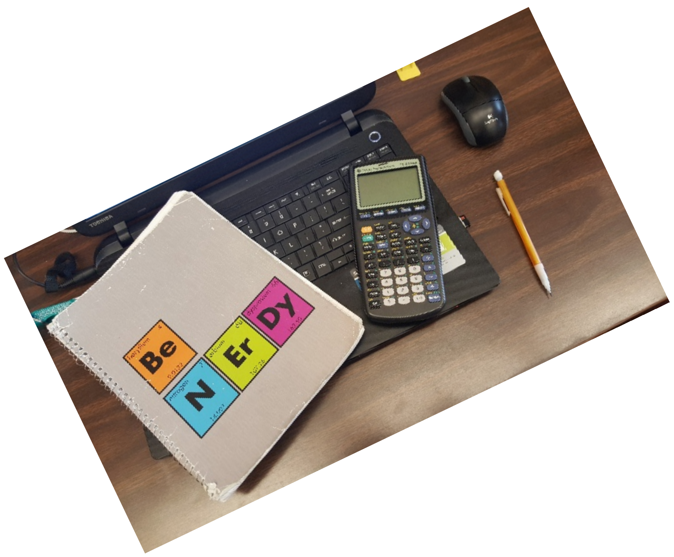
Liquid Argon Purity Monitor Testing

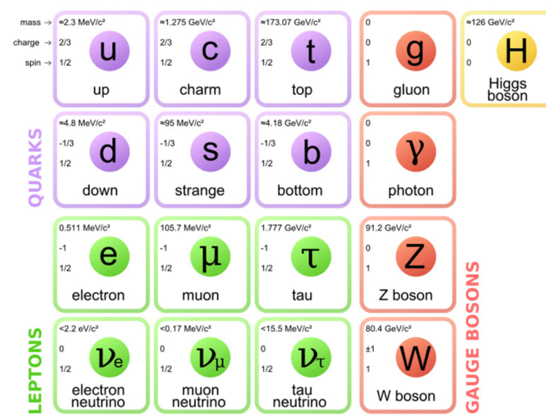
Bonnie Weiberg
TRAC Program

Summer, 2015

How I Spent my Summer Vacation, 2015

Fermilab





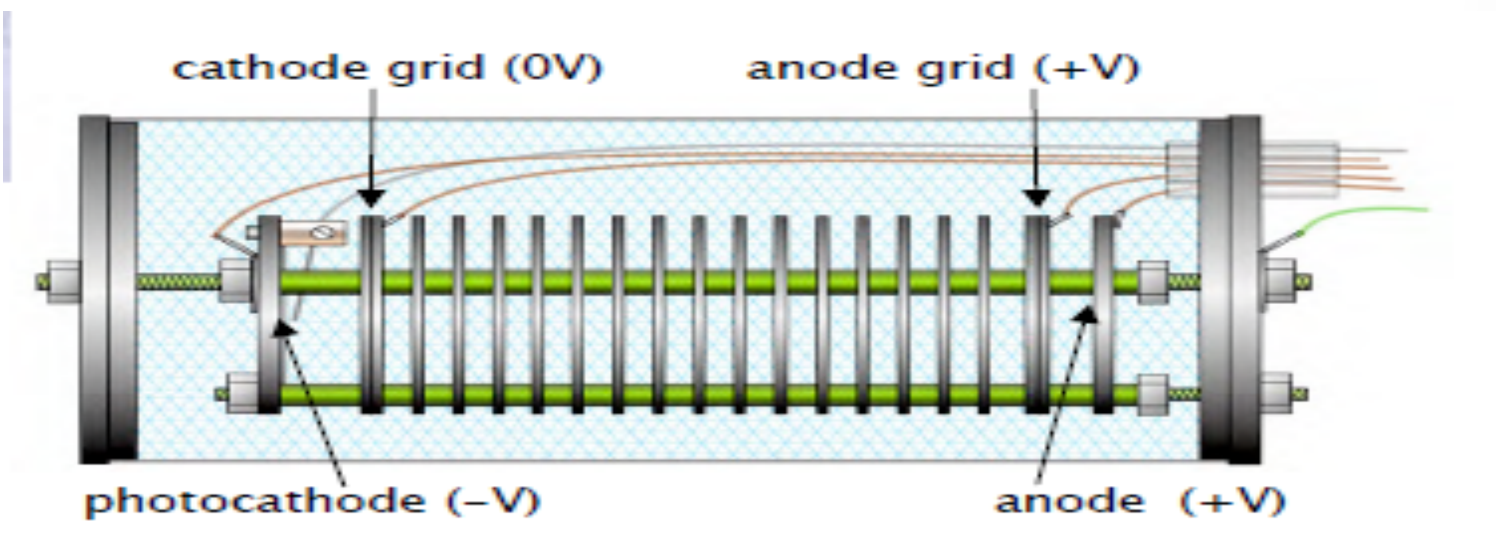
Purpose of My TRAC Project

- Measuring the Anode and Cathode Signal Strength for the short – 45 cm – Liquid Argon Purity Monitor.
- Analyzing the signals after the quartz optical fibers were cleaved using different devices.
- To measure the signal difference when an extension fiber was added via a connection through a PEEK coupler.
- This purity monitor will be installed in the 35 kiloton liquid argon cryostat as part of the DUNE Experiment.

Experimental Apparatus

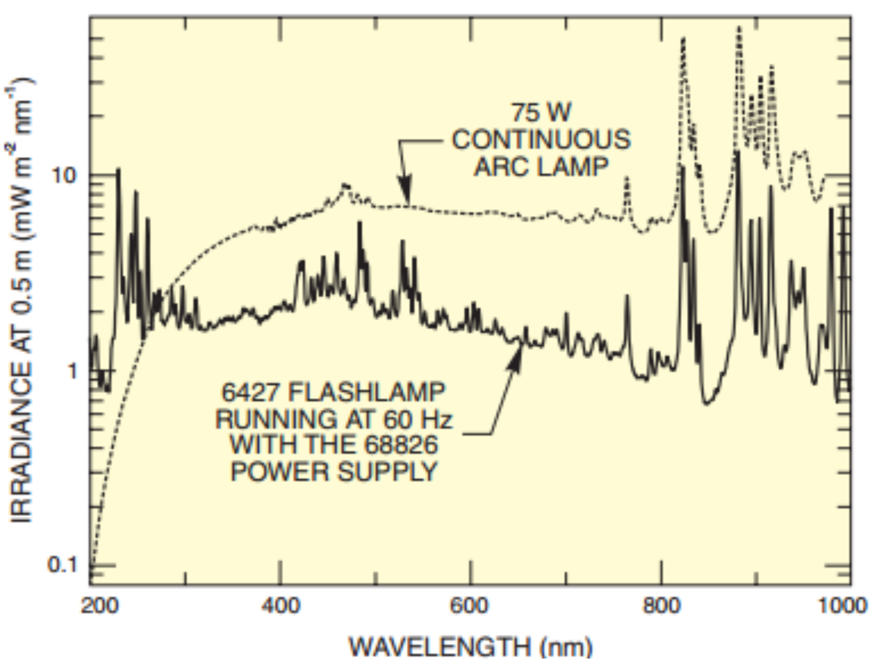
Experimental Apparatus

- The Short Purity Monitor is about 45 cm long.
- Optical Fibers are made of Quartz, surrounded by A Polyimide buffer.
- The Cathode is gold plated aluminum.
- Photons travel through the Quartz fibers to the Cathode and eject electrons that then travel through the electric field to the Anode.



Experimental Apparatus

- Xenon Flash lamp
- Flash lamp is Newport/Oriel Model 6427 Xe, 3x2.5 mm Large Bulb, 5J, 60W, 9 ms Pulse width, 60Hz Flash lamp
- Note that Au Work function is 5.1eV
- λ < 250nm to extract an electron



Experimental Apparatus

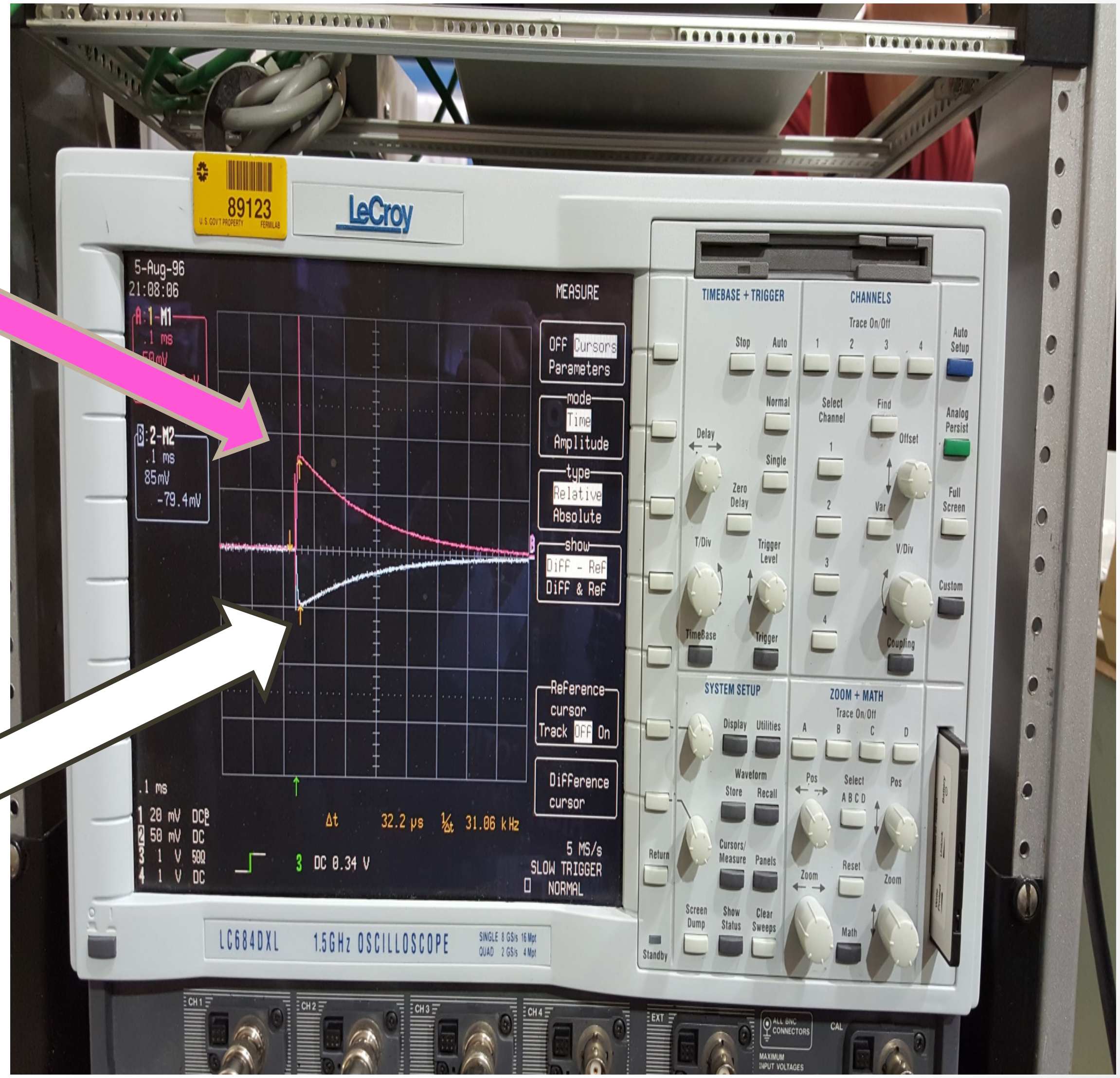
- Oscilloscope, Low and High Voltage
- Arm provided by Dr. Alan Hahn, at no extra cost to the presentation.
- ;)

Experimental Procedure #1

- After setting the Xenon Flash Lamp to 5000 mJ and 1 Hz, I adjusted the Cathode voltage to -100 Volts, and the Anode voltage to 400 Volts, producing an electric field of 500 Volts.
- I inserted the three fibers into the fiber holder and when they were against the flash lamp, I recorded the peak signals for both the cathode and anode. I repeated this procedure five times, removing the fibers completely, then reinserting them into the holder.
- I repeated the above procedure for each of the three individual fibers, five times each.

Experimental Procedure #1

- Anode Peak is here
- Cathode Peak is here



Experimental Data Summary

Vacuum:	6.5 x 10^{-5} torr	
Cathode (mV):	-100	
Anode (mV):	400	
Xe Flash Lamp:	5000 mJ & 1 Hz	
	# of Fibers = 3	
Trial	**Cathode (mV)**	**Anode (mV)**
1	-66.5	74.2
2	-73.1	71
3	-70	65.2
4	-63.8	63.96
5	-79.4	77.1
6	-71.7	67.1
7	-74.7	75.2
Average	**-71.3**	**70.5**

Experimental Data Summary

- After attaching a 1 foot fiber segment to fiber one using a PEEK coupler, the following data was collected:

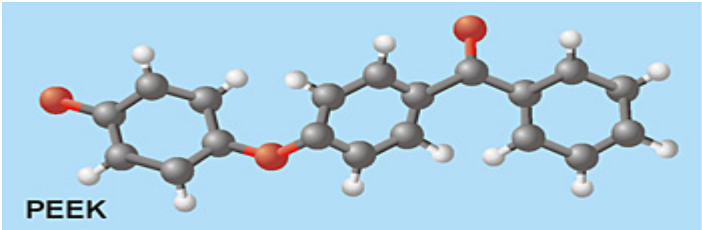
Fiber #1 with Coupler and Extension #1

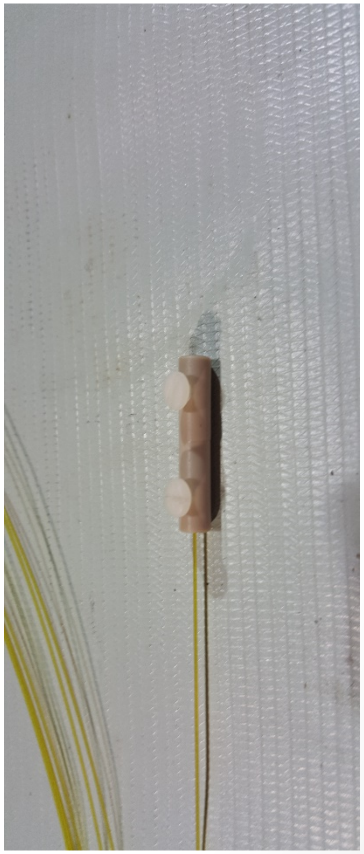
Trial	Cathode (mV)	Anode (mV)
1	-2.8	2.7
2	-2.7	2.7
3	-2.8	2.7
Average	**-2.8**	**2.7**

Fiber #1 with Coupler and Extension #2

Trial	Cathode (mV)	Anode (mV)
1	-10	10
2	-9.5	10.1
3*	-1.4	1.6

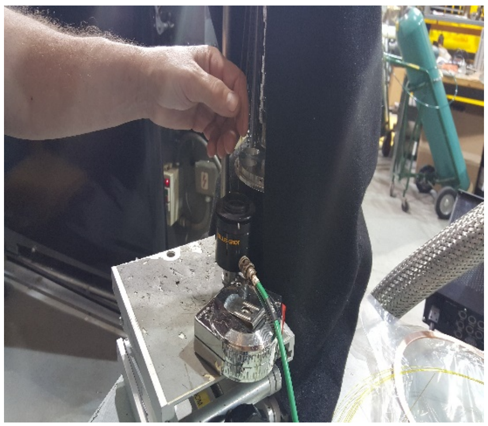
* = with optical grease

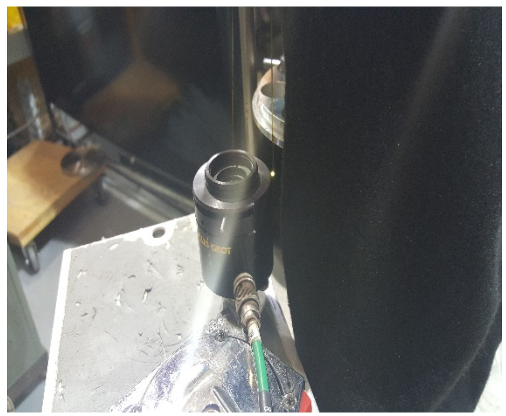


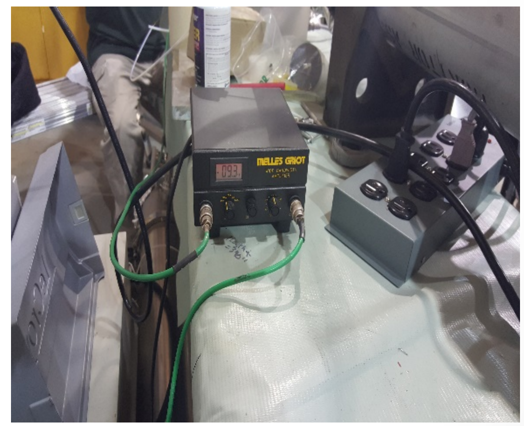


Experimental Procedure #2

- To check the individual fibers for their light transmittance, each fiber was placed into a Photodiode and the current was measured.



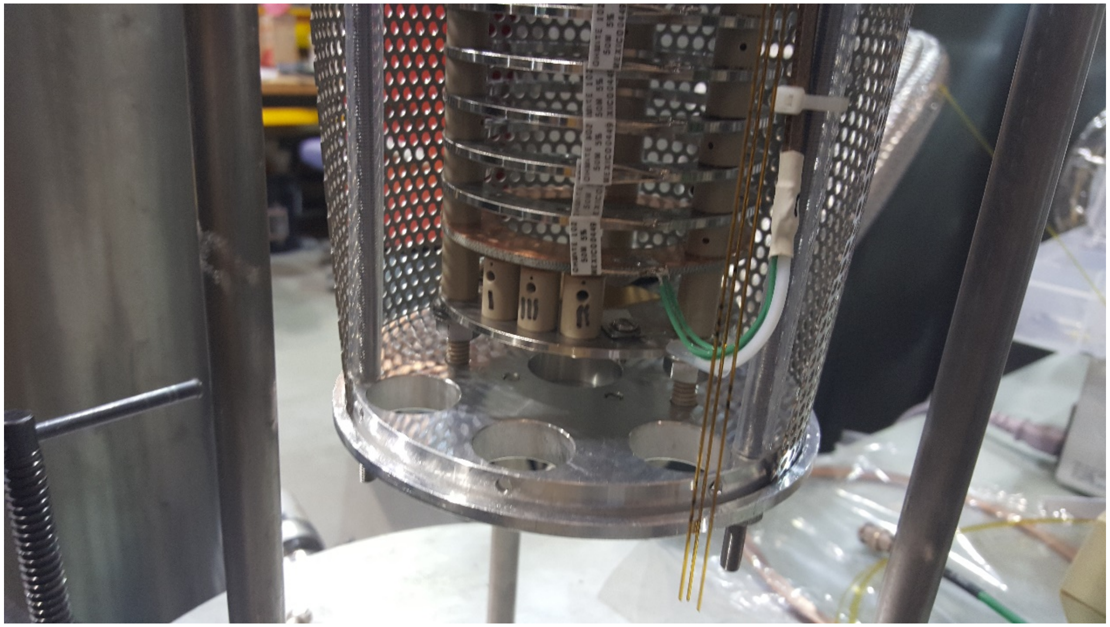




	Maximum Current Measured Using the Photodiode
Fiber 1	-51.2 µA
Fiber 2	-71.3 µA
Fiber 3	-59.2 µA

Experimental Procedure #3

- The fiber holders were then rearranged inside the Photocathode to check for cathode integrity.
- Their original order was:



- Holders 1 & 3 were switched.

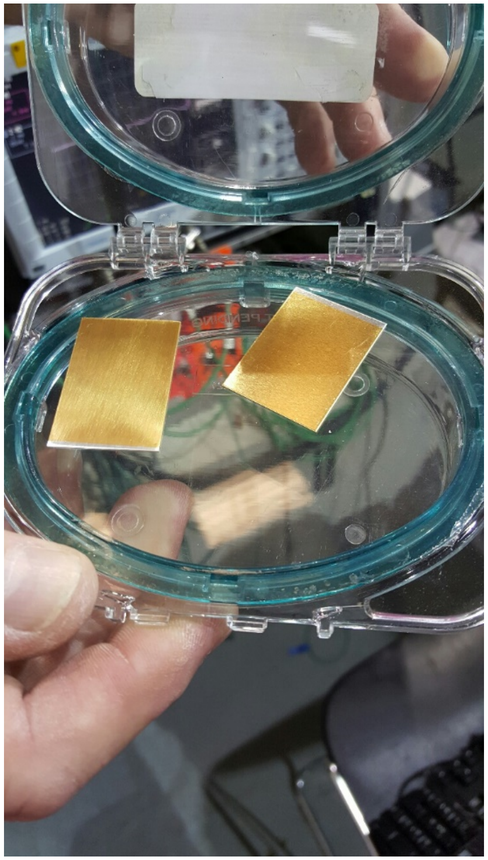
Experimental Data Summary

Date:	7/2/2015	
Vacuum:	5.0 x 10^{-5} torr	
Cathode (mV):	-100	
Anode (mV):	400	
Xe Flash Lamp:	5000 mJ & 1 Hz	
	# of Fibers = 3	
Trial	**Cathode (mV)**	**Anode (mV)**
1	-37.7	46.8
2	-28.3	38.0
3	-22.8	39.3
4	-22.3	38.6
5	-31.9	43.6
6	-47.6	53.6
7	-33.5	46.8
Average	**-32.0**	**43.8**

Experimental Procedure #4

- A new Photocathode was installed on July 7th by Mark Ruschman. His fingers are visible on the right.

- The system was returned to the vacuum chamber and the chamber evacuated.



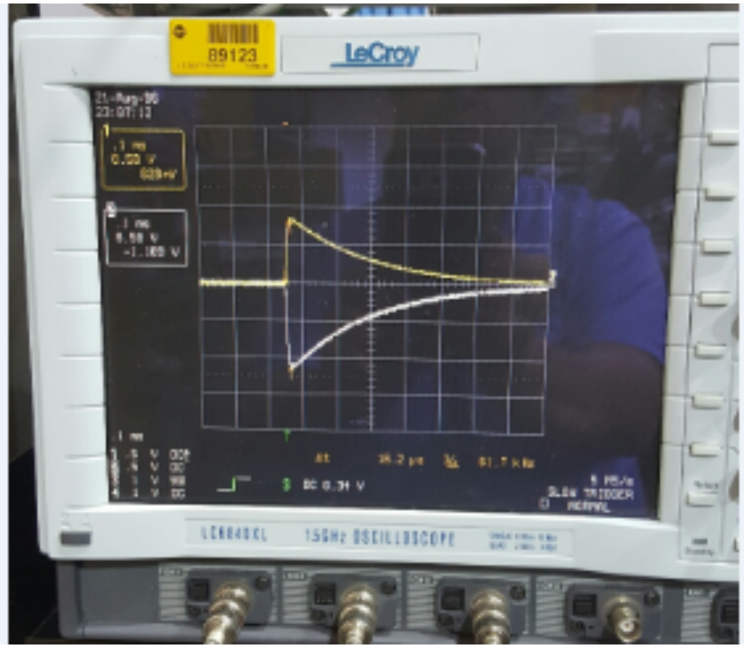
- Data was once again collected using the aforementioned procedure, with the same fibers, listed earlier.

Experimental Data Summary

- After the apparatus sat for over a week, under vacuum, base line readings were again measured.

Vacuum:	3.7×10^{-6} torr	
Cathode (mV):	-100	
Anode (mV):	400	
Xe Flash Lamp:	5000 mJ & 1 Hz	
	# of Fibers = 3	

Trial	Cathode (V)	Anode (V)
1	-1.359	1.031
2	-1.297	1.000
3	-1.379	1.047
4	-1.313	0.937
5	-1.344	1.016
Average	**-1.338**	**1.006**



Due to the new signal strength, the values are reported in Volts (**V**), not millivolts (**mV**)!!!

Experimental Data Summary

- A 32.9 cm Extension of fiber was connected to the long optical fiber with a PEEK coupler, held in place with Teflon screws.

Fiber #1 with Coupler and 32.9 cm Extension

Trial	Cathode (mV)	Anode (mV)
1	-40.0	15.0
2	-24.0	11.7
3	-24.0	15.0
4	-26.0	21.0
5	-26.0	12.4
Average	**-28.0**	**15.0**

Fiber #2 with Coupler and 32.9 cm Extension

Trial	Cathode (mV)	Anode (mV)
1	-24.0	16.4
2	-26.0	18.5
3	-24.0	17.3
4	-26.0	19.8
5	-26.0	18.2
Average	**-25.0**	**18.00**

Fiber #3 with Coupler and 32.9 cm Extension

Trial	Cathode (mV)	Anode (mV)
1	-24.0	17.1
2	-7.0	13.2
3	-18.0	13.1
4	-18.0	13.9
5	-20.0	14.6
Average	**-17.4**	**14.4**

Experimental Conclusions

- The Photodiode allowed for the checking of similar signals through each fiber.
- Using a coupler produced a decrease in the cathode and anode signals.
- Changing the Photocathode resulted in a huge increase in signal from both the cathode and the anode.
- Further investigation of the cleaving process of the Quartz fibers, including the possibility of removing the polymer protective coating, is needed to see if the signals can be amplified when a PEEK coupler is used.
- Dr. Hahn and Mark Ruchman will be investigating the use of a Quartz fusing apparatus to fuse the fibers together.

References

- 1. "Purity Monitor - Description and Experience at Fermilab."

  S. Pordes - FNAL May 13th 2006.

- 2. "Preliminary Results from Scan of Flash Lamp Radiation Pattern with a Quartz Fiber Mounted on an Adjustable three axis table."

  AAH + MR, November 20, 2015

- 3. Polymicro Technologies Silica/Silica Optical Fiber FV Specification Sheet, Molex, 2013.

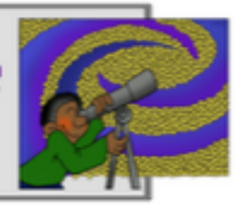
Classroom Applications

- Chemistry Unit 2: Hey Mr. Nucleus . . . It's Quark Time!!! =)

Learning Target	Performance Expectation
2-LT 1 I can describe the structure of the atom, including the relative locations, charge and mass of the subatomic particles.	**PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)
2-LT2 I can describe and write equations for nuclear reactions and discuss their applications.	**PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)
2-LT3 I can use atomic emission spectra to identify elements.	
2-PE-ESS 1-3 I can communicate scientific ideas about the way stars, over their life cycle, produce elements.	

Classroom Applications

PHYSICS UNIT 5: ASTRONOMICAL APPLICATIONS OF ELECTROMAGNETIC WAVES



Learning Targets	Performance Expectations
11-LT1 I can explain the process of energy production in a star. 11-LT1-A. I can **discuss** the process of fusion within a star. 11-LT1-B. I can **state** that the energy from fusion is released as electromagnetic radiation. 11-LT1-C. I can **explain** how the emission spectra from a star tells information about its composition, movement, and distance. 11-LT1-D. I can **discuss** the energy production and lifespan of the sun. 11-LT1-E. I can **explain** the process of sunspots and solar flares and the resulting variation in radiated energy. 11-LT1-F. I can **analyze** other masses and lifetimes of other stars to predict the lifespan of the sun.	11-PE1a. I can develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation. (NGSS HS-ESS1-1). 11-PE1b. Communicate scientific ideas about the way stars, over their life cycle, produce elements. (NGSS HS-ESS1-3).
11-LT2. I can explain the Big Bang Theory of the origin of the universe. 11-LT2-A. I can **discuss** the redshift of light from distant galaxies as evidence that the universe is expanding. 11-LT2-B. I can **explain** that the cosmic microwave background is remnant radiation from the Big Bang 11-LT2-C. I can **discuss** the observation that the composition of ordinary matter of the universe, primarily found in stars and interstellar gases matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).	11-PE1a. I can develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation. (NGSS HS-ESS1-1). 11-PE1b. Communicate scientific ideas about the way stars, over their life cycle, produce elements. (NGSS HS-ESS1-3).

mrsweiberg.com

Gratitude =)

I would like to thank Dr. Alan Hahn, Dr. Harrry Cheung, Dr. Pratima Jindal, Dr. Geoff, and Mark Ruschman for allowing me this amazing experience and for their support during this summer program. I honestly feel as if I have found my people.