Data Collection Calibration Project

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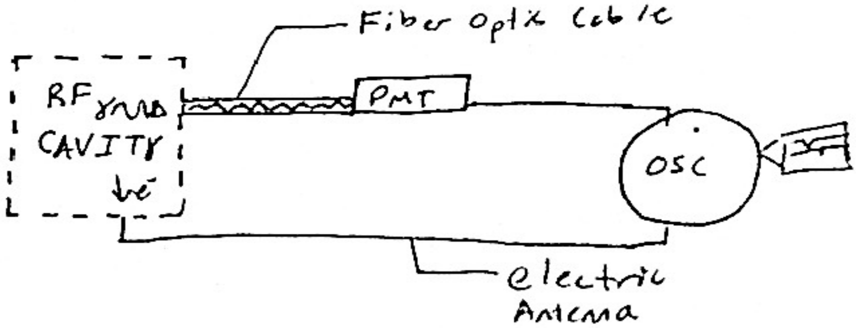
Introduction:

A Radio Frequency Cavity utilizes a contained electromagnetic field to accelerate charged particles. Sometimes, a breakdown occurs within these cavities. During Breakdowns, light and an electrical signal is released. In order to learn from these breakdowns, measurements must be taken from both the light and electrical outputs. For the electrical signal, this is as simple as connecting a cable to the electrical output and reading the amplitude of the signal. The light signal, however, must go through a Photomultiplier tube in order to convert into an electrical signal that can be measured. This difference in measuring paths results in a slight delay of when the electrical signal and light signal is read. Which because data is taken at a nanosecond timescale, results in a slight time difference between arrival times of the data.



Experimental Background:

The Radio frequency Cavity used in the experiment is very timely controlled and isolated. This means taking accurate measurements is important. Currently, small holes are used to allow access to visual and auditory sensors near the cavity. The physics that can be applied to these breakdown focused experiments are not very well understood, no model exists to explain the mechanisms that occur.

As such, one of the ways to try develop better models is to develop more precise measurement devices. However, along with precise measurements, differences in the data collection have more prominent effects. In our case, the precision of the experiment led to the emergence of perception of nanosecond misalignment of data. In the current method, the misalignment can be realigned to a more precise level. But the method is not consistent, and can introduce human errors. Thus, a method to align the data is needed.

The first resolution came in the form of resolving to know the misalignment of the data collection beforehand by taking calibration measurements between cables to simply add or subtract the misalignment data after the experimental data is collected.

<u>Current Method:</u>

The current method to resolve this delay is using a single laser pulsar that send an electrical signal simultaneously with a laser light pulse. The signal is then measured at an oscilloscope, the difference in arrival times of the pulses are determined and the known delay of the device is subtracted to obtain the relative arrival time delay of the pulses. The pulses are then aligned using an oscilloscope and the delay is noted.

Analysis of Current method:

Advantages:

The current method resolves the time delay by comparing one optical signal to an electrical signal.

These pulses are then aligned by hand on an oscilloscope, offering a coarse alignment of the data pulses.

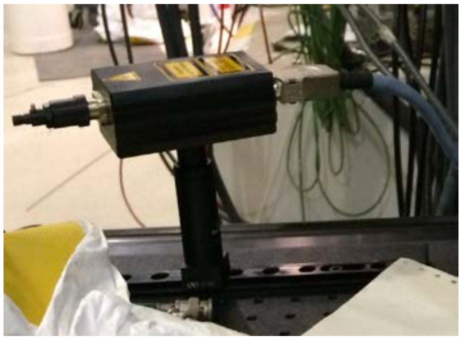


Figure1: Current caliboration device

Disadvantages:

There are main disadvantages with this system:

1. The process is slow, requiring an access into the hall each time.
2. After the data is returned, there isn't an easy way to quickly obtain the information desired.
3. Only one wavelength of light can be tested (based on the parameters of the laser).

In short, the device works, but is very time costly, especially because multiple channels are used during data collection in the experiments, not simply two. Additionally, the alignment process can be inconsistent with changing users and measurement device (in this case the oscilloscope).

The goal is to make calibration data collection easier and quicker as well as making data analysis of the calibration measurements more consistent.

Mission Statement:

To design a system for taking and analyzing calibration data to resolve the relative arrival time difference of the optical and electrical signals.

Design Goals:

Following are the Goals of the final design:

1. The design resolves the time delay between the PMT and antenna channels.
2. The design allows multiple inputs.
3. The design is intuitive and easy to use.

Hardware:
Due to time constraints. We were unable to fully design the device that will release multiple signals. However, the preliminary design is as follows.

In figure 2. The device is shown. The cylindrical design allows a reduction in external noise to impact the timing of the signals. The holes on the external sides would be fitted to accept fiber optic cables and electrical cables to take multiple signals at once.

The material needs to be strong in order to be machined accurately to further reduce timing variation. Additionally, a coating will applied to the inside to reduce reflection noise from the signal generation.

A square wave generator with a high rate will generate a square wave to activate the LED. This will release both an electrical signal through connecting the cables in parallel to the LED, and an optical signal by the flash from the LED.
In general, the same data collection hardware can be used to take measurements.

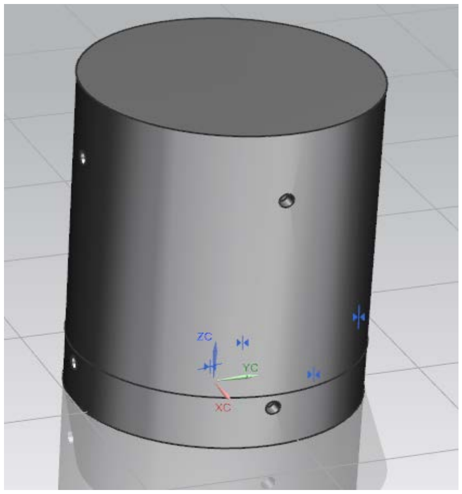


Figure 2: Solid model of preliminary design of the device. The dimensions are 20cm height with a 15 cm diameter top.

Software:
The software is done using Matlab in order to make calculation and parameter inputs simple.

Inputs:
Inputting files of certain file types and establishing of parameters are all done through the use of dialog boxes. This allows the user to be able to properly understand the purpose and usage of the parameters.
Documentation written to go along with the program explain the uses and purpose of the program input files.

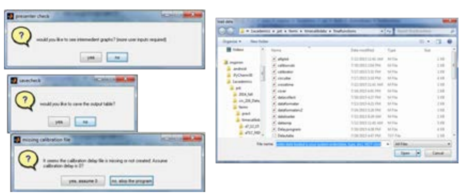


Figure 4: Example of how the input dialogs are expressed.

Outputs:
The program outputs a table that shows the amount of delay calculated between all the channels given to compare. As can be seen in figure 5. The table reads as, “vertical channel + delay in the box aligns with the horizontal channel”

	ch 1 (1)	ch 2 (0)
ch 1 (1)	0	3.3519e-08
ch 2 (0)	-3.3519e-08	0

Figure 5: Example table

Features:

In order to make the experience easily supervised. The program offers the feature to inspect certain graphs. This keeps the user involved by showing the sections of data that go into aligning the data, and showing the alignment of the data after the delay is applied. [Figure 6].

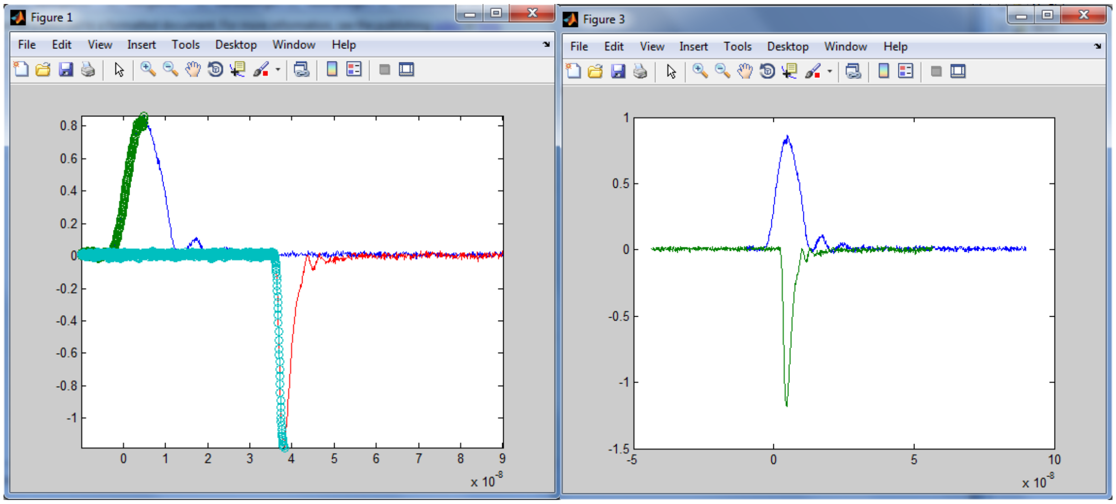


Figure 6: (left) plot of a pulse of data as it is read into the oscilloscope. (right) plot of a pulse after calibration time is implemented.

Error:

The most pertinent source of variation that can arise from the program is a variation cause by the parameters the user specifies. For example, when the user specifies the threshold voltage, the voltage reading at which the light source in this case and LED, would release a light signal, it is with the knowledge that there can be variations in the threshold voltage due to manufacturing variations. From data sheets, most LEDs vary in threshold voltage by 0.1V, which results in a total possible variation in delay calculated by about .1ns, which is only one order of magnitude below the scale of the calculation.

Environmental effects can also change the way the program can miscalculate the delay. Most importantly, this can be due to temperature changes in the cables or environment where the measurements are taking place. Serious variation in temperature have a small change in the threshold voltage of the Led, but due to thermal expansion of the wires, the delay can be changed as well.

Future work:

For the future consideration, reducing environmental effects and part variation should be addressed. This would allow the program's outcome delay to reflect more correctly the existing delay between the cables, and allow calibration to be more reliable.

Additionally, as the designs were in the preliminary design phase, with a focus on the software for data collection and analysis, there will be issues in the physical design that may be introduced from manufacturing techniques that were not discussed in detail.