Speed of Light

Aaron Koga
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I. ABSTRACT

This experiment attempted to measure the speed of light. A light emitting diode (LED) provided light, which traveled in a tube and was detected by a photomultiplier tube (PMT). The time of travel for the light was measured by a time to analog converter (TAC), whose output was interpreted by a multi channel analyzer on the back of a computer. Using the time and the measured length of the tube, the speed of light was calculated to be $3.4(10^8)\pm.6(10^8)$ m/s. This agrees with the theoretical value of $3(10^8)$ m/s.

II. INTRODUCTION

The speed of light is known to be about $3.00(10^8)$ m/s. All electromagnetic radiation, including visible light, travels at the speed of light in vacuum. The first measurements of the speed of light came from observations in astronomy. With the development of fast, precise electronics, the speed of light can be measured in the labratory. [(1)]

III. APPARATUS

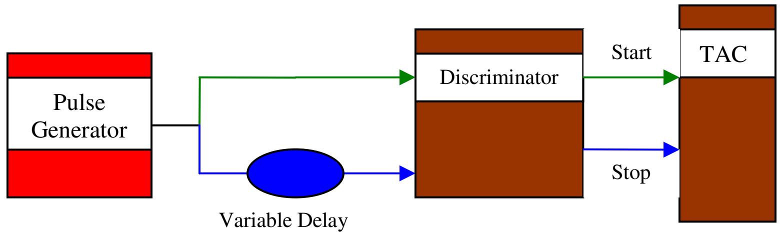

Figure 1: Calibration setup.

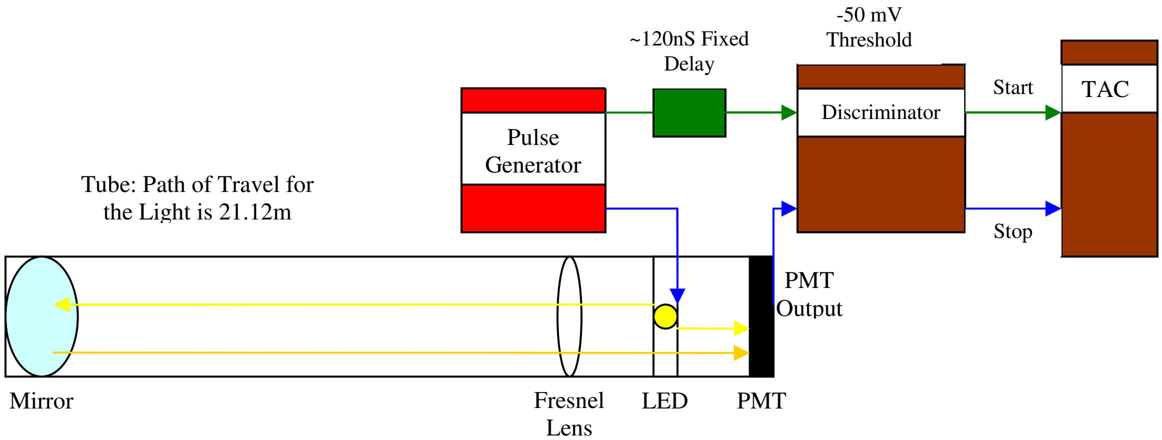

Figure 2: Experimental setup for determination of the speed of light.

The experimental setups shown in Figure 1 and Figure 2 were used. In the setup of Figure 2, an LED, Fresnel lens, mirror, and PMT were placed in a light-tight tube. Pulses were sent to the LED from a pulse generator. The LED, was located near one end of the tube. The light emitted from the LED reflected from a mirror placed at the other end of the tube. Both the emitted and reflected pulses were detected by the PMT (driven at 1200V). The output from the pulse generator and the PMT were discriminated. The discriminated signals were sent to a TAC that used a 200ns scale. The discriminated pulse generator output determined the start time and the discriminated PMT output determined the stop time. The TAC output was fed to a multi channel analyzer on the back of a computer.

IV. PROCEDURE

The setup in Figure 1 was used to calibrate the TAC output for a TAC scale of 200 ns. The output from the pulse generator was split. One signal was used for the TAC start. The other signal was delayed (by a known amount) and used for the TAC stop. The TAC output was determined as a function of the delay.

The setup in Figure 2 was used to determine the speed of light. Data was recorded by the computer for about 45 minutes.

V. CALCULATIONS

The TAC was calibrated by fitting the data to a line. The small value of χ^2/ndf indicates that the TAC is linear for the range 0-200ns.

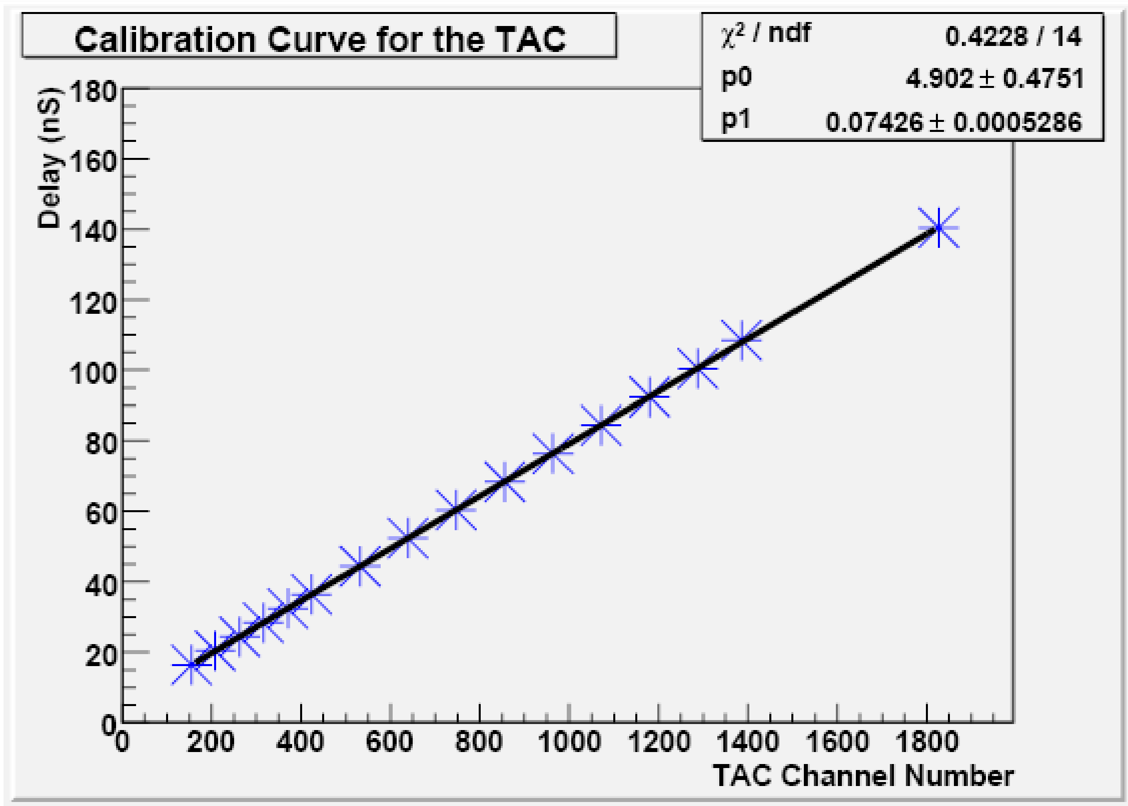

Figure 3: Calibration for the TAC. Fit equation: 4.90x+.074

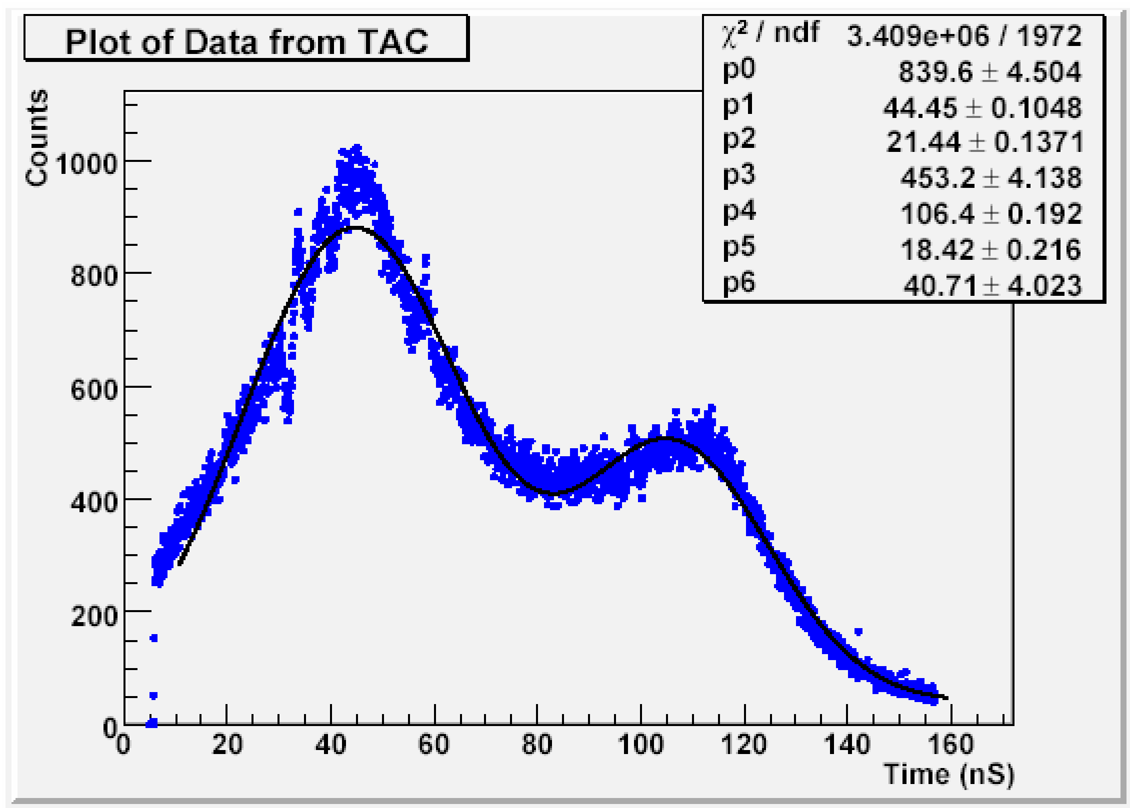

Figure 4: Data to determine the speed of light. Fit equation: $839e^{-\frac{1}{2}(\frac{\text{Time}-44.4}{21.4})^2} + 453e^{-\frac{1}{2}(\frac{\text{Time}-106.4}{18.4})^2} + 40.7$

Figure 4 shows the data used to determine the speed of light. The flat offset is due to light reflections from the sides of the tube. The speed of light is calculated from the equation: c = L/t. L is the length the light travels in the tube, which was 21.1±.1m. t is the time it takes for the light to travel in the tube. t is also the distance between the two peaks of the Gaussian distributions (44.4nS and 106.4nS) used to fit the data. The first peak corresponds to the detection of the primary pulse from the LED while the second peak corresponds to the reflected light from the mirror. The error in c is calculated from the equation: $\Delta c = \sqrt{\left(\frac{\Delta L}{t}\right)^2 + \left(\frac{L\Delta t}{t^2}\right)^2}$, where ΔL is the error in L and Δt is the error in t. Δt is a combination of the statistical error and systematic error in t. The statistical error is the sum of the error in the position of the Gaussian peaks (Figure 4). The systematic error was determined by fitting different functions to the data. Various Gaussian distributions, exponentials, and linear functions for the background noise were used in different combinations. The statistical error is .25ns and the systematic error is 10ns.

The calculated speed of light is $3.4(10^8) \pm .6(10^8)$ m/s.

VI. CONCLUSIONS

The theoretical value for the speed of light is $3.00(10^8)$ m/s. This agrees with the calculated value of $3.4(10^8) \pm .6(10^8)$ m/s. The large error in the speed of light is due to the systematic error. A large systematic error seems reasonable because the peaks from the fitting function do not coincide with the peaks in the data and the χ^2/ndf value is very large.

VII. REFERENCES

1. *Speed of Light*. Wikipedia. http://en.wikipedia.org/wiki/Speed_of_light.