Speed of Light

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Overview

In this lab we will try to determine how accurately the speed of light can be measured with a function generator, photo-detector, oscilloscope, laser, and a mirror. We will need stands for your laser and mirror capable of making small adjustments to the projected angles. In doing so we will also recommend improvements to the experiment so better data may be obtained.

Procedure

Connect your function generator by use of a t-splicer to both your oscilloscope and to your laser so that you have a zero point for measurements and reliable periodic pulses of light coming from your laser. In case the lag time for returned pulses from your laser is on to large a scale the location of your mirror at its first position will be used as a zero point for both measurements of change in time and distance; it is in both cases nice to have a reliable trigger. It will be easiest to set up all electronic equipment in one location of a room or long hallway then project the laser some distance to a mirror and back to the photo-detector that will also be attached to your oscilloscope. This is done so that only the mirror will need to be moved to make changes to the distance the light needs to travel to reach the detector. Here you can see that it is necessary to have both the laser and mirror on stands where fine adjustments can be made so that final incidence with the photo-detector will result in clear pulses on the oscilloscope. It may be useful as well to have your photo-detector on an adjustable stand as small differences in the angle at which your photo-detector receives pulses makes a large difference in your ability to resolve pulses in the nano second range we hope to be in the scale of. The closer you can keep the laser and the detector the easier it will be to maintain proper alignment as you move the mirror back, this will also allow you to make a small angle approximation for the distance the light travels from the laser to the detector. Your set-up should be similar to the diagram shown below. Your function generator should be set to produce a square wave of peak voltage that is consistent with proper voltage allowed for your laser.

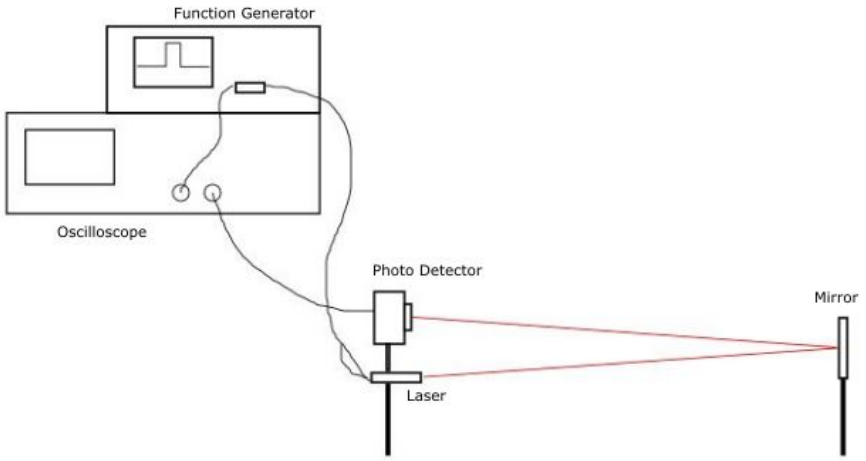

Figure 1: Basic set up

Data

Here the accuracy of our data was limited by our ability to read the rising edge of the incoming pulse from the photo-detector. We were able to make decent approximations for the rising edge of our incoming pulse when the time scale of our oscilloscope was set to $40ns$ and the voltage scale was set to its minimum value. As well careful alignment of optical equipment such that the laser directly illuminates the photo detector greatly improved our ability to read the rising edge of the incoming pulse. The distance for which we were able to make measurements in was also limited by the total range of times we could evaluate with our oscilloscope set at this specific time resolution, as well as the ability to maintain culmination of our beam. Admittedly more measurements could have been made at intermittent distances to alleviate improper evaluation do to random error and to improve analysis by best fit method. The slope of the graph below gives our best guess for the value of the speed of light with data points marked as the change in distance from the first placement of the mirror and the associated change in time for the function generator to receive a pulse compared with the pulse received from the original placement of the mirror. Our weighted best fit was obtained by utilization of the scipy.optimize package of python and the standard deviation of our best estimate was taken as the square root of the covariance also obtained with the scipy.optimize package.

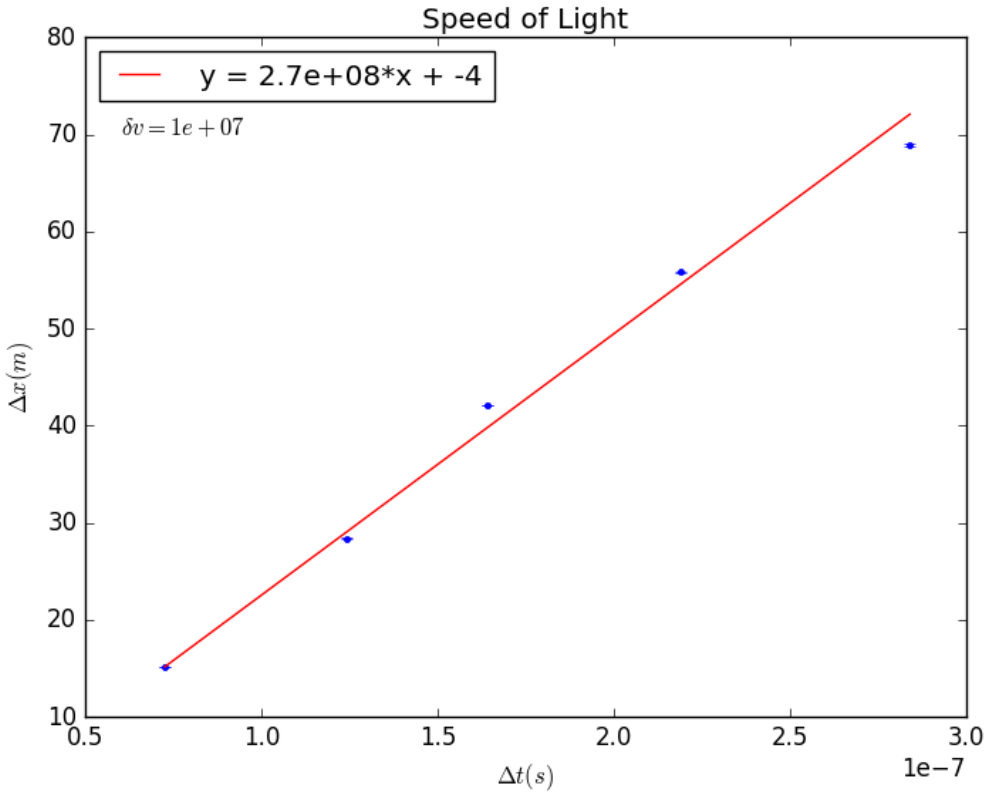

Figure 2: Best fit for speed of light

Using this method a best estimate for the actual speed of light with error was made as $(2.7 \pm 0.1)\ x\ 10^8\ \frac{m}{s}$

Conclusion

Our value for the speed of light fell well outside of the range of the actual value of the speed of light given the uncertainty in our best guess. I do however believe that this discrepancy is not do to systematic error but instead do to random error given the difficulty in our ability to evaluate the actual change in time for each returning pulse. This error could be reduced by increasing the number of intervals at which we took measurements from but this as well has a maximum value discerned by our ability to tell the difference between starting points of incoming pulses from the photo-detector. Given careful scrutiny, at best we might obtain roughly twice as many data points which I do not believe would be statistically significant.