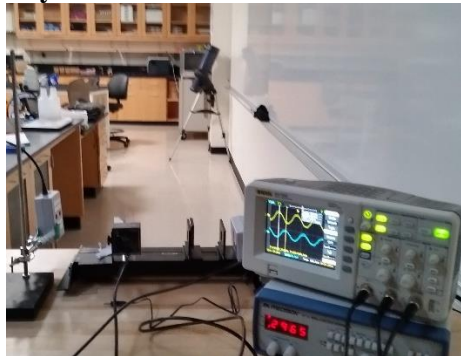


## Physics 197 Lab X: Speed of Light Measurement

### Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Red laser	Pasco AP-8586		Group	1			
Photodetectors	Pasco AP-8586		Group	2			
Lens for Photodetector with Holder	Pasco AP-8586		Group	1			
Magnetic Rail	Pasco AP-8586		Group	1			
Glass slide beam splitter and holder			Group	1			
Prism Corner Cube Array	Edmund 47322		Group	1			
Pick off mirror or prism			Group	1			
100 MHz Oscilloscope	RIGOL DS1102E		Group	1			
5 MHz Function Generator	BK Precision 4011A		Group	1			
BNC to BNC Cable			Group	1			
Laser Drive Cable	Pasco AP-8586		Group	1			
Photodetector output cables	Pasco AP-8586		Group	2			
Meter Sticks			Group	-			
Blue Floor Tape			Group	-			
Turning mirrors on stands			Group	4			

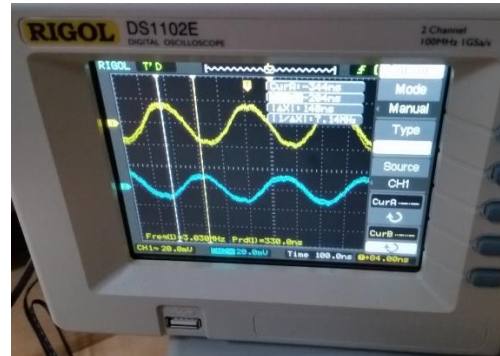
### Layouts:



Setup for Speed of Light Experiment with Laser bouncing off mirror at far end of room



Prism corner cube array and beam splitters



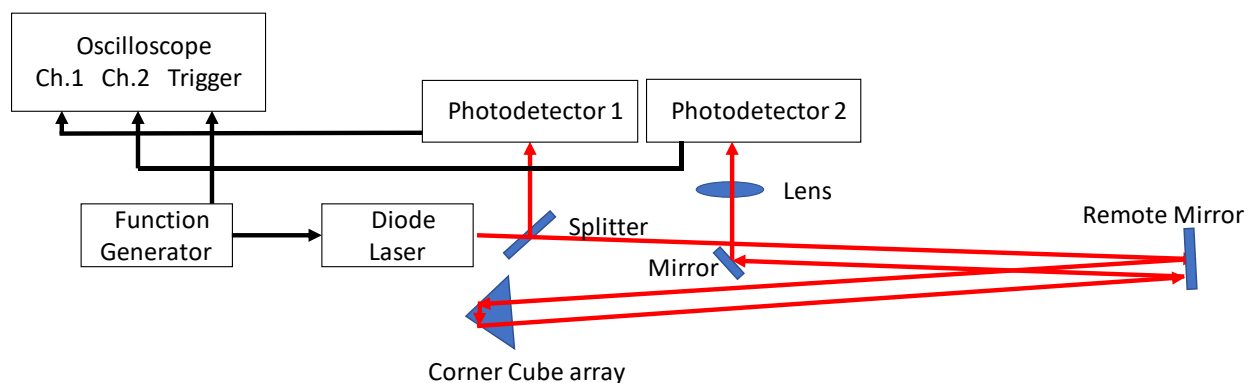
Oscilloscope output showing 140 ns offset

### Summary:

In this extra credit lab, students will work as a group to measure the speed of light. A laser modulated with a 3 MHz square wave is directed via one or more mirrors to a prism corner cube array which returns the laser along the path it came from. A glass slide beam splitter near the laser output directs about 8% of the light to a first photodetector, which is monitored on channel 1 of an oscilloscope. The return light from the mirrors and corner cube array (retroreflector) is directed via a collecting lens to a second photodetector which is monitored on channel 2 of the oscilloscope. As the path length to the retroreflector and back is increased, there is an increasing time delay between the first and second photodetector signals. The total light path distance is divided by the time delay measured on the oscilloscope to obtain the speed of light.

## Laboratory setup:

This is an extra credit lab in which everyone should be able to participate with the same apparatus. The instructor should set up a function generator, oscilloscope, diode laser, two photodetectors and associated optics as in the following diagram.



### Laser Speed of Light Optical Layout

The function generator should be set up with an output signal of about 3 MHz (for instance a square wave) which is used both to drive the laser diode and externally trigger the oscilloscope. The offset voltage and amplitude should be adjusted so the diode laser is driven from just below threshold to a maximum current during the time period of the output signal. The output laser signal can be optimized by observing some portion of the light split off into detector 1 and monitored on channel 1 of the oscilloscope. Because of various limiting bandwidths in the Pasco system, the output light signal will appear as a sine wave when optimized, as seen in the top (yellow) trace in the third photograph on the first page of the write-up.

The main part of the laser beam is directed to a remote mirror and reflected back to a corner cube prism array. It is advantageous to use such an array as compared to a mirror because the light is directed back towards the laser on approximately the same path it came out on, independent of mirror vibrations and other mirror alignment irregularities. Because the size of the beam expands as it propagates due to self-diffraction, it is possible to direct a good portion of the returning light through a lens to a second photodetector without blocking the output beam. The lens or photodetector position should be adjusted to maximize the signal observed on channel 2 of the oscilloscope. If things are set up properly, there should be two sine wave signals on the oscilloscope with a time delay between them, as in the third photograph referenced previously. As the path length is increased by moving one or more remote mirrors further and further away, the time delay will increase, and the change in path length divided by the change in time delay should equal the speed of light.

### Group procedure:

The instructor should make a table on the white board with a row for each student, and columns having student name, laser pathlength, measured time delay, and a checkmark that each student changed the path length. An initial round trip path length should be set out by the instructor (for instance 20m, with a mirror 8 m away from the setup reflecting light to a corner cube array located 2 m from the mirror.) This initial distance should be measured with a meter stick (remembering to double the one way path length) and marked on the white board. The time delay should be measured with the oscilloscope and also marked on the white board. Students should then take turns increasing the distance to the corner cube array by 1 meter at a time (2 m increase in round trip path length), while another student measures the new time delay. (It is useful to use the cursors on the oscilloscope for this). Each student should take a turn changing the path length, and each student should take a turn measuring the time delay. Extra mirrors can be used to go around corners or outside the laboratory room. All of the data should be tabulated on the whiteboard.

**Laboratory Analysis:**

Please tape this whole write-up in your lab notebook. This week, it will not be necessary to do a prelab or document the procedures. When the class has finished taking data, please make a table in your lab notebook giving the measured path lengths and the measured time delays. Using a whole page of the lab notebook (appropriately scaled based on the range of data), plot time delay vs. path length. Put the path length on the horizontal axis since it is being changed in even increments. Put a best fit line through the data points (by hand, but using a straight edge) and calculate the slope (for instance in ns/m). Take the inverse of this slope (which should be the speed of light) and compare it to the known value of  $3 \times 10^8$  m/s. Have your lab notebook checked off by the instructor before leaving.