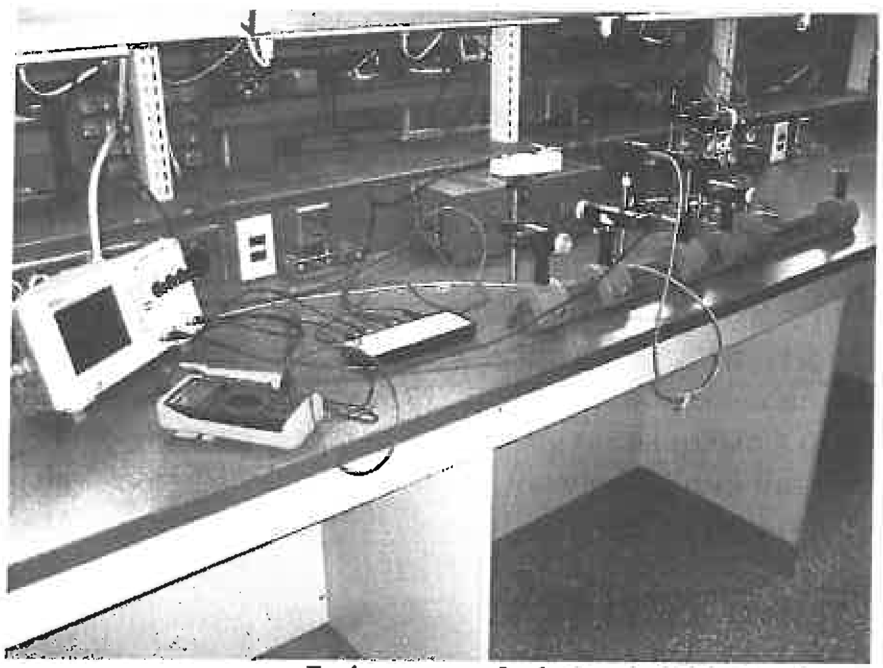
Speed of Light Experiment

Purpose: to measure the speed of light by using a pulsed laser.

Experiment: The method used in this experiment is by "time of flight". Other methods, like that of a rotating mirror, was one of a number of earlier methods by which the speed of light can be obtained. One of the easier techniques to understand is by taking measurements of the optical pulse delay with different path lengths traveled. From this data, the slope can be obtained from which the speed of light can be deduced.



Equipment setup for the Speed of Light Experiment

Setup: The laser used is a low power laser pointer, removed from its casing and mounted on a Teflon block. The laser emits light at a a wavelength of 650 nm.which operates in the voltage region of 3-5 v. In order to generate a short pulse from the laser, it was biased just below the threshold (5 – 10 mA) of lasing and then pulsed with a high current short spike that would enable lasing with an optical pulse of a few nanoseconds. These high current (50 to 100 mA) short electrical pulses come from a transistor (2N2369 NPN) circuit operated in avalanche mode. The shape of the optical output pulse depends on the driver circuit components.

[For additional info. As regards the circuit used, go to http://www.elexp.com/t_SpeedofLight.htm]

The optical pulse initially passes through a beam splitter. Part of the pulse is reflected by the splitter to a high speed Si pin detector (ThorLabs PDA 10A 150MHZ BW)...mounted close to the laser. The pulse that travels through the beam splitter travels a long path (a longer time delay) before returning, passing through a lens, and focused onto the detector. A lens is needed as the returning laser light has high divergence.
The detected pulses and delay are measured on a 50 MHZ Rigol oscilloscope.

Initial alignment of this arrangement is made by changing the bias on the laser allowing it to operate in its CW (Continuous Wave) mode. The path of the laser to its return mirror and detector are traced with a slip of paper held to intercept the beam. Mirrors, beam splitter, lens, are brought into alignment. Delays are measured and the optical distance is noted and changed. Further realignment may be necessary.

Following the laser beam...

Follow the laser beam as it leaves the laser. You will see the beam pass through a partial reflective (mirrored) glass slide which is acting as a beam splitter. One part of the beam reflects back to the detector. The other part passes through the splitter and then through a mirror with a hole in it. Note that this beam will be taking the longer path. See below. The mirrors direct the laser to what is called the last mirror, after which, the beam is returned to the mirror with the hole in it. The beam has diverged over the long distance and so when it arrives back at the mirror with the hole in it, it is too big to go through the hole, and so most of it is reflected to a mirror which directs the returned beam through a lens which focuses it also on the detector. When the laser is pulsed, two pulses will be seen on the oscilloscope...an earlier pulse reflected from the beam splitter (taking a short path) and a second delayed pulse that being transmitted through the splitter took the longer path back to the detector. The delay time between these two pulses are read and recorded from the oscilloscope.

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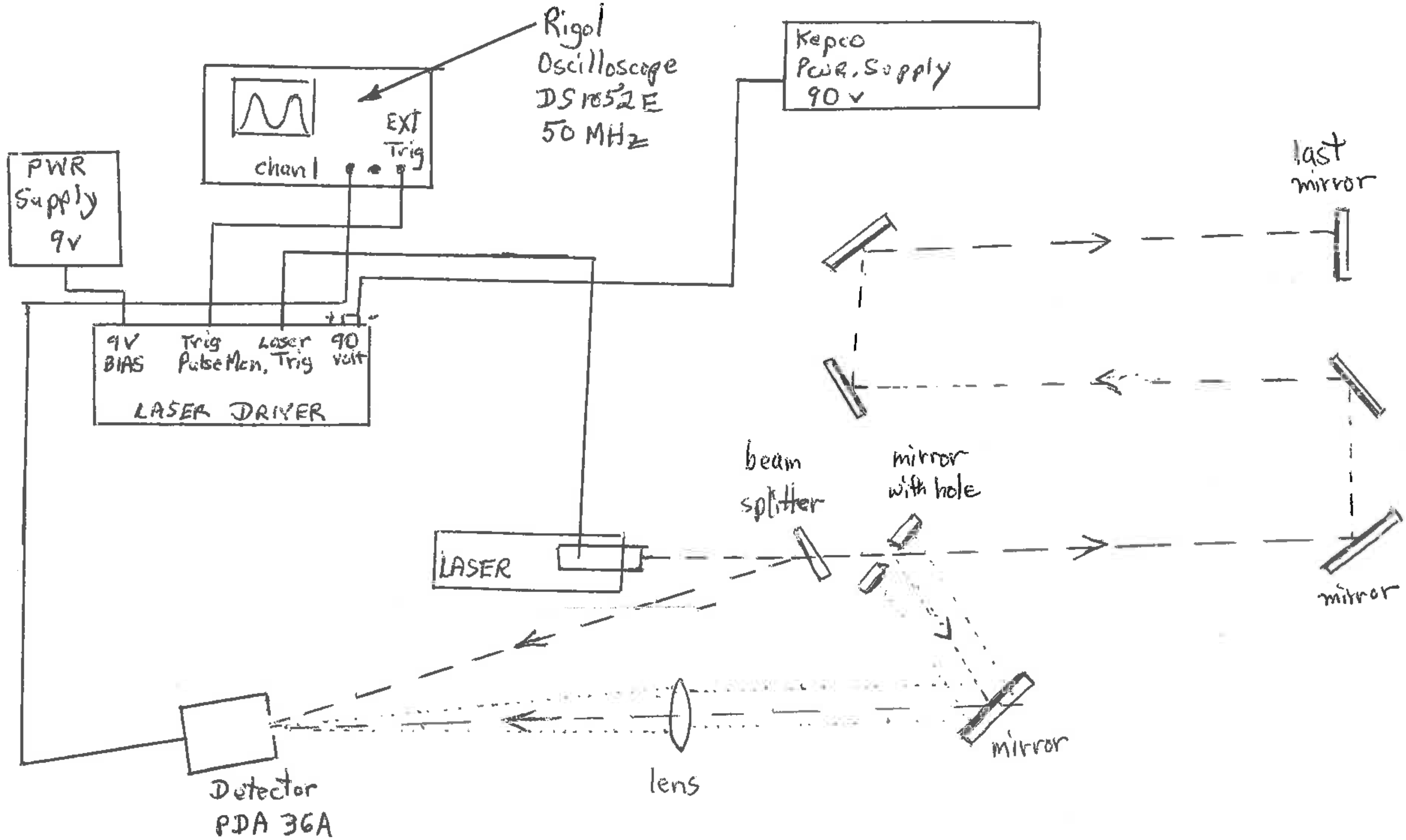

Aligning the laser beam...

Aligning the mirrors for the outgoing pulse taking the longer path...is simply adjusting the mirrors one by one so that the beam is centered on each following mirror up to and including the last mirror. The beam is continually diverging over its distance travelled. The last mirror is adjusted so as to return the beam reflects on itself. To do this, place a plate with a hole in it about 8 or 10 m away in the return path. Set the plate in the path so that the outgoing beam passes through the hole centered in the hole as seen from the outgoing laser side. Now, with the last mirror, adjust the return diverged beam to be centered on the opposite side of the plate. Remove the plate so that the beam continues back to the mirror with the hole in it. Check and align if necessary for the beam to pass through the lens and onto the detector.

After you align, check that you have two pulses on the oscilloscope screen. By changing the mirror just before the lens, you can adjust the peaks of the pulses to be similar amplitude , and then stop triggering the pulse on the scope. Adjust the pulses to fit vertically and horizontally on screen and note the time/div. scale on the lower right corner of the screen. Look where the slope of each pulse crosses the horizontal center scale and mark down the time lapse between pulses.

Take a secondary mirror and place it in the path a distance away from the last mirror. Let this become your last mirror and realign the return beam using the plate with the hole. Note the distance from the previous last mirror position and record this distance from your new present position. The actual change in distance is twice what you recorded. Note also that the time has now changed in the two pulse position and record the time.

Repeat different mirror positions and continue to record your data. Your points should be graphed giving you a line, the slope from which you can arrive at a value for the speed of light.