

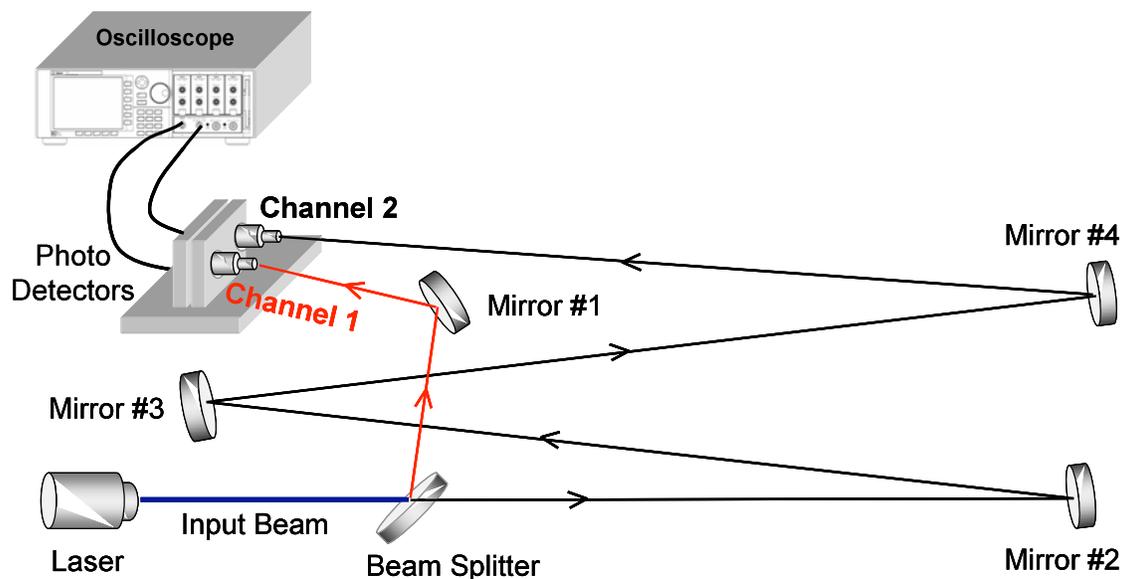
3.003 Lab 3 –Part A. Measurement of Speed of Light

Objective:

To measure the speed of light in free space

Experimental Apparatus:

Components: 1 Laser, 4 mirrors, 1 beam splitter (splits a beam into 2 beams), 2 detectors, 1 oscilloscope, connectors



Section 1 – Laser signal setup

- 1) Plug output of PG 502 generator into CH1 of HP54800B scope.
- 2) Apply power and press Autoscale on scope.
- 3) Press the Autoscale button on the scope.
- 4) Press the Measure Time button, and then the Frequency button on the bottom of the display and adjust the Time per Div if needed to get an accurate frequency reading. There must be at least two pulses on the display for the algorithm to work.
- 5) Adjust the PG502 Variable Period knob as required to obtain 1.0 MHz pulse frequency.
- 6) Set Time per Div as required to measure pulse width (10 ns per Div typical).
- 7) Press Measure Time, Next Menu at bottom of display, then “+Width”.
- 8) Adjust Pulse Duration Knob on PG502 as required for 50 +/- 1 ns.
- 9) Set the PG 502 Low Level and High Level knobs as required to obtain a baseline of near zero volts and the flat part of the top of the pulse to +5.0 V.
- 10) Disconnect PG502 from scope CH1 and connect to laser diode on optical table.

- 11) Please note that the red laser light will be visible emanating from the diode.
- 12) Do not increase the duty cycle or voltage settings on the pulse generator to avoid overheating the laser diode.

Section B – Optical setup and measurements

Please use the schematic on page 1 as a reference

- 1) Dim the room lights as needed to be able to see the laser light.
- 2) Use a white card to trace the beam from the source to the first mirror on the right edge of the optical table.
- 3) Next trace the beam from the mirror #2 to mirror #3.
- 4) And now trace beam and adjust as required to hit the center of mirror #4.
- 5) Finally adjust mirror #4 as required to place the beam in the center of the dual PIN photo diode detector.
- 6) Adjust the reference path mirror (mirror #1 the shorter path) as required to get the beam centered on the photodiode closest to the front of the optical table. You will not need to adjust the beam splitter – it is already preset in position.
- 7) Connect the reference path photo detector output coax cable signal to CH1 of scope.
- 8) Connect the long path photo detector output coax cable signal to CH2 of scope.
- 9) Connect the Trigger Output of the PG 502 to the External Trigger input of the scope.
- 10) Press the Autoscale button on the scope.
- 11) Set the Time per Div knob clockwise as required to get 10 ns.time base setting.
- 12) Set the Vertical Position knobs as required for the CH1 signal to have its baseline in the center of the display and the CH2 baseline to be at -3 Div on the Display.
- 13) Press the Measure Time button, then the Next Menu button on the bottom right of the display twice to find the Delay menu.
- 14) Press the Delay button and measure the time difference between the two signals.
- 15) Please note that the scope algorithm measures to the 50% point on the rising edge of each waveform.
- 16) Estimate the time uncertainty of this measurement by looking at the jitter in these readings.
- 17) Press the Display button on the Scope and select the Average Mode of display acquisition. Set the # of Averages to 256 and wait for enough scans to have been acquired before recording the Delay time in nanoseconds.
- 18) Measure the laser beam Reference Path Length accurate to approximately 1 cm using the inch based tape measure and converting the inches measured to meters. The optical table grid is on 1.00 inch centers and that may be helpful as a double check of the accuracy of the individual path length section measurements.
- 19) When measurement is finished set the Display mode back to normal.

Calculate the speed of light, estimate your error and compare to literature.

3.003 Lab 3 –Part B. Measurement of Velocity of EM Waves in Coax Cables

Objective:

To measure the velocities of electromagnetic wave in two coax cables with different lengths.

This is a non-optical setup. For each cable, you will use a pulse generator and a scope to measure the time of travel, then measure the length of the cable and calculate the velocity of the wave. The spec states that the speed of a signal traveling down the coaxial cable is 67% of the speed of light. The electromagnetic wave traveling down the cable is actually the same thing as light, just at a different frequency (on the order of 10^9 Hz; the visible light has a frequency on the order of 10^{14} Hz).

Procedure:

- 1) Plug the output of PG 502 generator (square wave) through a splitter into CH1 of HP54602B scope using a reference cable, and into Ch2 using another cable with the same length. Connect the trigger output of the function generator to the trigger input of the scope.
- 2) Apply power and press Autoscale on scope.
- 3) Press the Autoscale button on the scope.
- 4) Adjust the PG502 Variable Period knob as required to obtain 1.0 MHz pulse frequency.
- 5) Set Time per Div as required to measure pulse width
- 6) Press Measure Time, Next Menu at bottom of display, then “+Width”.
- 7) Adjust Pulse Duration Knob on PG502 as required for 100 ns.
- 8) Look at the waveform on the scope. Are they really square?
- 9) Now connect the cables to the scope again through the connectors with 50 Ω loads. How about the square wave now? Do you know why?
- 10) Compare the signals between CH1 and CH2. Is there any delay between the two?
- 11) Now substitute the cable on CH2 with a long cable. Do you see any changes on the scope? Do you know why?
- 12) Now let us measure the amount of time delay between the two channels. How would you change the time scale to get a more accurate measurement?
- 13) Press cursor button on the scope.
- 14) Press t1 on the bottom and move the cursor to the middle of the rising edge of channel 1
- 15) Press t2 on the bottom and move the cursor to the middle of the rising edge of channel 2
- 16) Now the time delay between t1 and t2 is displayed on the screen. Is it stable enough? How would you make it more accurate?
- 17) Measure the length of the coax cable and convert to meters.
- 18) Calculate the velocity of the EM wave through this cable.

Answer the following questions:

1. What was the velocity of the EM wave in each cable? What percentage of the speed of light?
2. Can you think of the reason why the speed of the signal measured in a coaxial cable is slower than the speed of light?
3. Find online how people measured the speed of light well before the invention of electronic devices. We will discuss about it in the next lecture.

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