The Speed of Light

Goals

- **Measure the speed of light in the lab**

Overview

The speed of light in a vacuum is about 3×10^8 m/s. In this lab, we will measure the speed of light using a pulsed laser and two PIN photodiodes.

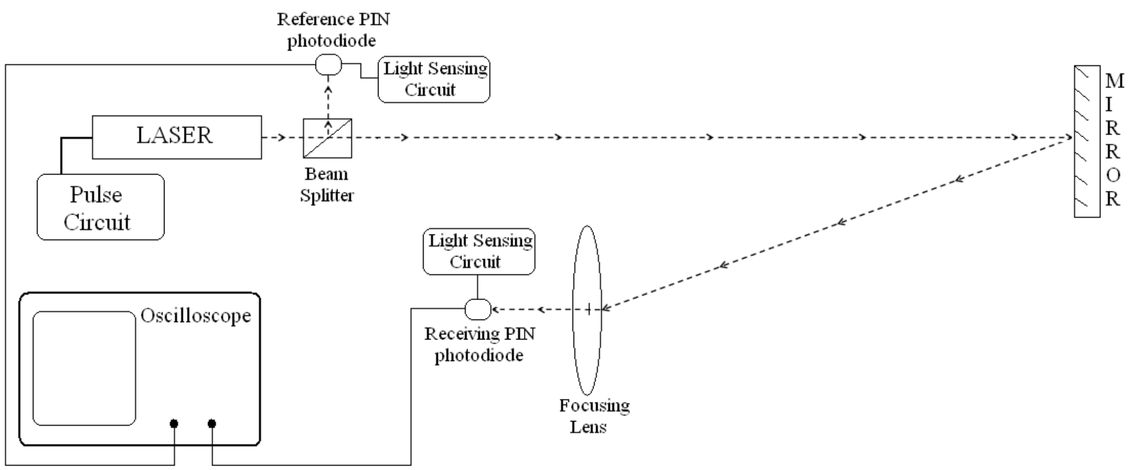

Figure 1 – Lab set up diagram showing the optical path

Figure 1 shows the diagram of our lab set up. The dashed lines show the path of the light beam. The light beam first hits the beam splitter, which consists of two triangular glass prisms glued together so that half of the incident ray is reflected about ninety degrees to the reference PIN photodiode. The remaining light beam goes straight to the mirror, which reflects the light through the lens. The lens focuses the light on the receiving PIN photodiode.

As you can see in **Figure 1**, the reference PIN photodiode is connected to channel 1 on the oscilloscope and the receiving PIN photodiode is connected to channel 2. Diodes can either emit light or act as light sensors. When light hits both PIN photodiodes, two waveforms will appear on the display.

Pre-Lab Question 1

a) How far in feet does light travel in one nanosecond?

b) A group of Penn students is trying to measure the speed of light. The distance between the reference and receiving PIN photodiodes is 60 feet. How long will it take for the light to complete the path?

A PIN diode has an intrinsic layer of high resistance material between the P and N layers of a “normal” diode. This layer is what gives our photodiodes an incredibly short response time of 2 ns. The quick response time is crucial for the success of this lab because the speed of light travelling over the relatively short distance in lab is so fast.

When the light beam hits the PIN photodiodes, current will flow through the circuit. It is important to understand that the oscilloscope graphs the voltage across the pulse circuit and not the current.

The PIN photodiode is a part of the light sensing circuit, which also consists of a 5 volt power supply and a variable resistor called a potentiometer, or ‘pot’ (these are not shown in Figure 1). The pot is sometimes needed to obtain the best signal because diode behavior changes with the frequency of the signal.

The pulse circuit consists of a transistor circuit and a function generator. The transistor circuit is located in the metal case with the laser. The frequency of the pulse can be adjusted using the function generator. The time between pulses should be faster than the round-trip travel time of the light beam. However, the frequency cannot be too high because the capacitance effect of the diodes will distort the display on the oscilloscope.

Pre-Lab Question 2 How fast a pulse rate will be necessary to accurately measure the speed of light? Explain your answer.

Procedure

You should know how to use the oscilloscope before doing this procedure. Refer back to the write-ups and power points for double zero lab and speed of pulses lab

1. Connect "Hi" jack on the Wavetek generator to channel 1 of the oscilloscope.
2. Set the function generator to square wave.
3. Using the 'amplitude' and 'DC offset' knobs, set the square wave to have a maximum value of 12 volts and a minimum value of -7 volts.
4. Disconnect the function generator from the oscilloscope and connect it to the laser.
5. Using the mirrors provided, construct a path through which the laser beam can travel and return to the receiving diode.
6. Turn the laser on to make sure there are no obstructions in the path.
7. Focus the light beams on the PIN photodiodes. The light should be focused on the small, black speck in the center of the diode.
8. Note: The amplitude of the graphs on the oscilloscope will displace from zero to five volts if everything is set up correctly.
9. Use the function generator to set the frequency.
10. Make sure the oscilloscope has the correct settings. To reduce noise, go to ACQUIRE and select the ‘Averages’ option. The pot may need to be adjusted if the signal is not strong enough.

Questions

1) How does your measured speed of light compare with the accepted value of the speed of light? Explain any causes of error.
2) The speeds of computers are increasing rapidly. 300 MHz machines are readily available today. In one cycle of a 300 MHz computer, how far could a light beam travel? (Electricity travels in a wire at around ½ the speed of light).
3) What is the distance travelled in one cycle of a gigahertz machine? How might this present physical problems with the spacing of components in the computer?