Measuring the speed of light through a Fiber Optic material

Speed of Light Fiber Optic Set
Oscilloscope with BNC cable, Banana Plugs and BNC – Banana Plug Adapter

Our intention is to measure the speed of light traveling through a 20m length of a plastic fiber optic material with an index of refraction which the manufacturer states is 1.5. Remember that the index of refraction relates the velocity of light in a vacuum to the velocity of light in that medium. While 1.5 may not be exact, for this measurement we will be satisfied with the reported index.

Determine the relationship between the speed of light in a vacuum and the speed of light in a medium. Write it here:

To experimentally determine the speed of anything that moves at constant speed, what parameters do you need?

Develop an experiment that will allow you to measure these quantities for a sliding cart on an air track and record it here:

Develop an experiment to measure the speed of light in a fiber. Be conceptual, for example, you know you need a light source but you do not need to specify what light source. Record your conceptual steps here.

When you reach this point, bring this sheet to the instructor (one per group).

Measuring the speed of light through a Fiber Optic material-Cont'd

At this stage you realize that you need a light source, a starting time (a trigger) and an ending time (or receiver/detector). The light source (laser), trigger and detector are mounted on the circuit board provided. This apparatus generates light pulses at 1MHz. The timing device we will use is a digital oscilloscope. The oscilloscope must be triggered when the pulse is sent and it must measure the same pulse after it travels through the 20m segment of fiber. An electro-optic transmitter outputs a voltage pulse when the light pulse is generated. A light receiver also outputs a voltage pulse when light is detected. These two voltages should be the inputs to channel 1 and 2 on the oscilloscope. The time of flight is the difference in positions of the two pulses, emitted and received.

The most difficult part of this lab is detecting the signals output from the circuit. Determine an estimated time interval for the flight of the light through 20m of fiber. From this calculation you should be able to determine a time scale to use on the oscilloscope. The output voltages from the trigger and detection devices are between 0.25V and 3.0V so you can roughly set the voltage scales to channels 1 and 2.

To get an accurate measurement of the time of flight, it is important to make sure no offsets in time exist due to a delay in the circuitry or the oscilloscope. The circuit creating the light, emitting the light and detecting the light is configured with a potentiometer which allows you to adjust the time (delay). "Short" between the transmission side of the device and the receiver side of the device using the short length of fiber. Estimate the error this "zeroing" may introduce to your measurement. In any case, we assume this length is effectively zero and that the emitted and received pulses should occur at the same time. Adjust the delay knob until this situation is realized. You have now calibrated the device and are prepared to make the measurement.

Determine the speed of light in the fiber and in a vacuum. Summarize what you have done and your results.

For those of you who have not used an oscilloscope, you want to trigger off of the emitted pulse so you must set the trigger source to channel 1. Trigger mode should be auto, slope should be positive (or rising), both voltage inputs should be AC coupled (not DC or Ground) and the display mode must be set to Dual or Alt.

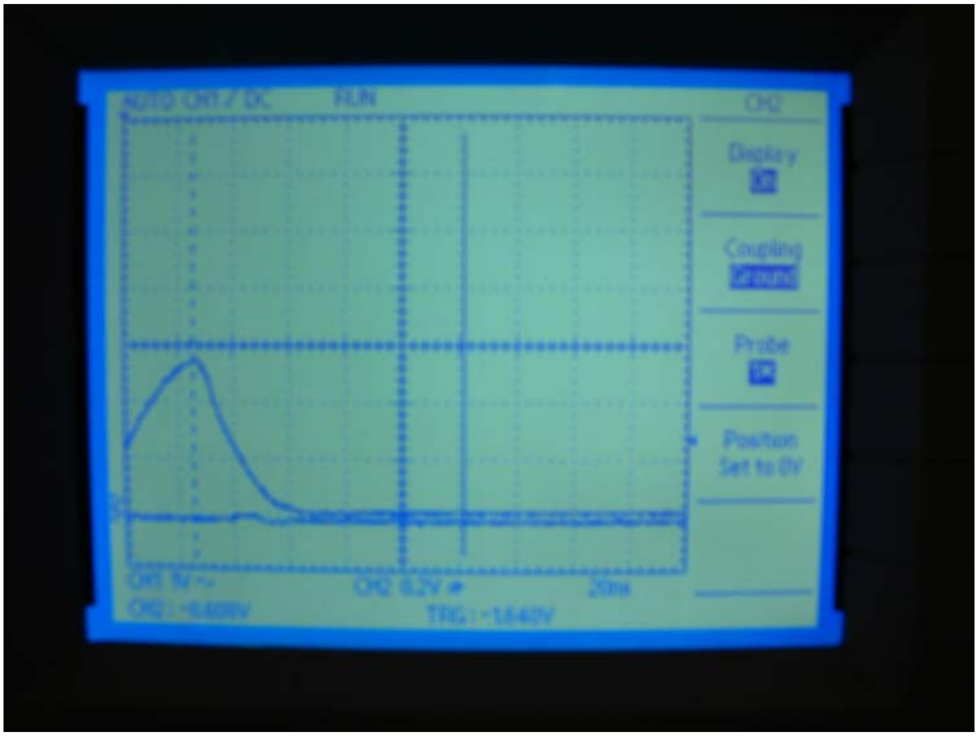

Figure 1 Initial pulse before light is transmitted through fiber.

To get an accurate measurement of the time of flight, it is important to make sure no offsets in time exist due to a delay in the circuitry or the oscilloscope. The circuit creating the light, emitting the light and detecting the light is configured with a potentiometer which allows you to adjust the time (delay). “Short” between the transmission side of the device and the receiver side of the device using the 15cm length of optical fiber. Since this length of fiber is 0.75% the length of the long fiber, it is well within the errors created by our uncertainty in the index of refraction. In any case, we assume this length is effectively zero and that the emitted and received pulses should occur at the same time. Adjust the delay knob until this situation is realized. You have now calibrated the device and are prepared to make the measurement.

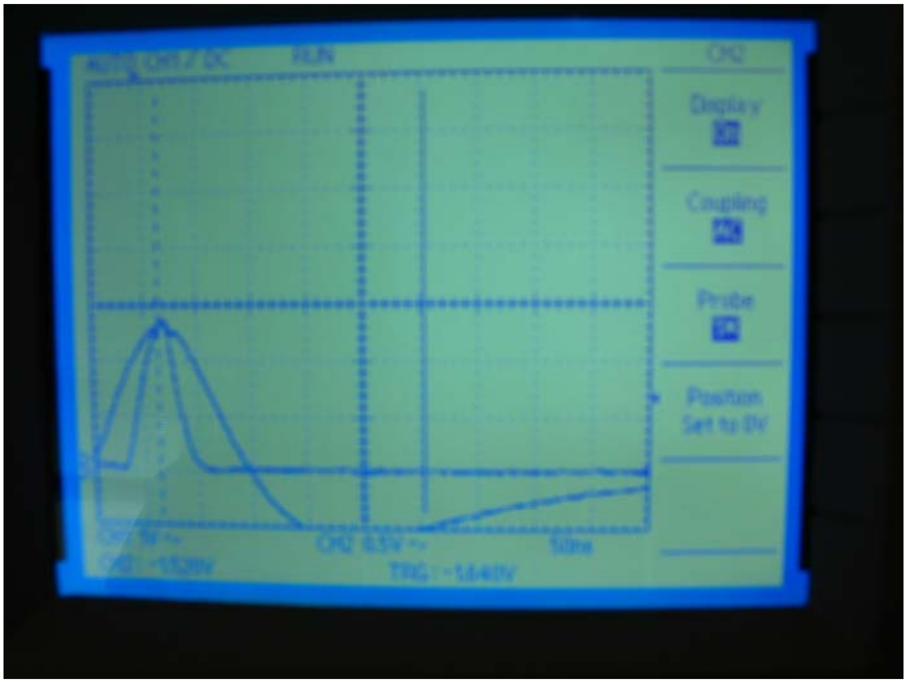

Figure 2 intial pulse and detected pulse through 15cm of fiber.

Replace the 15cm length of fiber with the 20m length. Measure the time of flight of the light and calculate the speed of light in the fiber. Finally, convert the speed of light in the fiber to the speed of light in a vacuum.

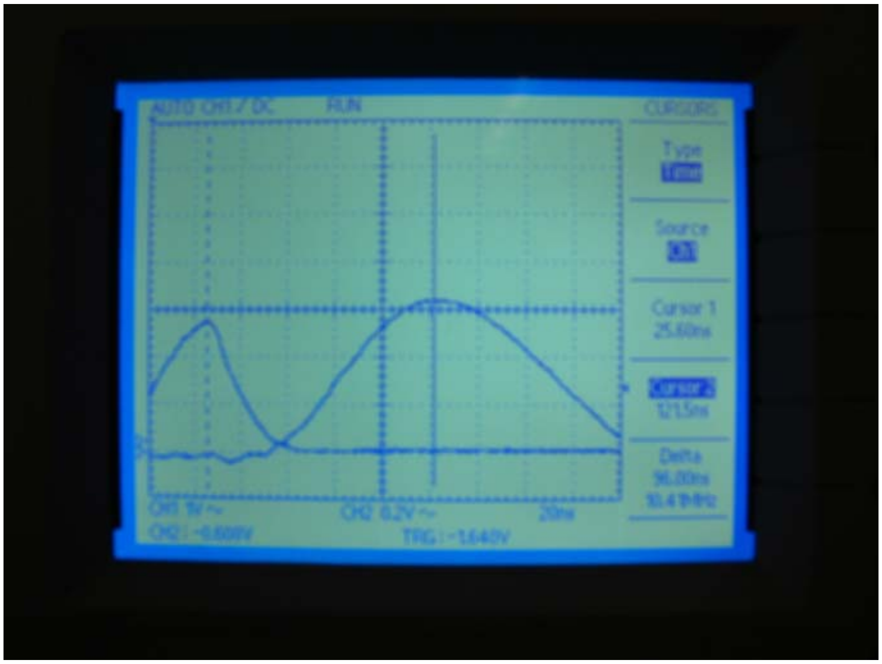

Figure 3 Initial pulse and light after passing through 20m of fiber.