SPEED OF LIGHT IN A FIBER OPTIC CABLE

Object: To measure the speed of light in a fiber optic cable.

Equipment needed: Light pulse transmitter and detector, power supply, 15 cm of plastic fiber, 20 m of plastic fiber, dual-channel oscilloscope (at least 20 MHz bandwidth), two oscilloscope probes.

Theory: Internal reflection of a light beam can occur when the index of refraction of the material containing the incident beam is higher than the index of refraction of the surrounding material. When the angle of incidence is greater than arcsine(n_o / n_i) total internal reflection occurs and the light can be guided by the optical fiber. To check that the index of refraction of the clear material in the optical fiber has a greater index of refraction than the surrounding medium you can measure the speed of light and calculate the index of refraction. The index of refraction is defined as the ratio of the speed of light in vacuum over the speed of light in the material (n_i = c / v_i).

Preliminary Setup

1. Turn on the oscilloscope.
2. On the oscilloscope make the following settings:
   A. Set the horizontal mode switch to A.
   B. Set the triggering mode on auto.
   C. Set the trigger source switch on channel 1.
   D. Set the triggering on positive slope.
   E. Set the voltage control of input channel 1 on 1 volt per division.
   F. Set the voltage control of input channel 2 on 0.5 volt per division.
   G. Set the input coupling of both channels on ac.
   H. Set the time base on 50 nanoseconds per division
   I. Set the vertical mode to ALT.
3. Connect the probe of channel 1 to the (blue) test point marked "Reference" on the light pulse transmitter.
4. Connect the ground lead of channel 1's probe to the ground test point just below the Reference test point.
5. Connect the probe of channel 2 to the "Delay" (blue) test point on the light receiver.
6. Connect the ground lead from channel 2's probe to the ground test point just below the Delay test point.
7. Turn channel 2's input selector to the "ground" position.
8. Plug the connector of the power supply into the receptacle on the left side of the apparatus. Plug the ac power cord into a 120 vac 60 Hz receptacle. As soon as power is supplied to the apparatus the yellow light emitting diode (LED) should light up. D3, the fiber optic LED, should also be visible if you lean down to look sideways into the front of the blue fiber optic housing on the right side of the apparatus.
9. Turn the "Calibration Delay" knob on the apparatus to the 12 o'clock position.
10. Loosen the fiber optic cinch nuts on the fiber optic LED D3 (blue) and the detector D8 (black).
11. Select the 15 cm length of plastic fiber and insert one end of it into LED D3 until it is seated, then ***lightly*** tighten the fiber optic cinch nut.
12. Insert the other end of the optical fiber into detector D8 until seated, then tighten its fiber optic locking nut.

Calibration

The time required for light to traverse 15 cm of fiber optic cable is less than one nanosecond, for our purposes, zero. Ideally, the electrical pulses at the "reference" test point and the light pulses at D3 would be exactly synchronized, and the electrical pulses at the "delay" test point would occur at exactly the same time as the light pulses arriving at D8. Any delay between a pulse the reference test point and the delay test point would ideally represent the time for the light to traverse the cable. However, this ideal situation does not exist because of delays in the electronics of both the apparatus and the oscilloscope. The purpose of the calibration is to adjust out the delay due to the electronics.

1. You should now see a pulse on channel 1 of the oscilloscope. It should be approximately 3.5 volts high and 35 nanoseconds in width at half maximum.
2. Turn on channel 2 from "ground" to "ac" coupling. A second pulse that is 1 to 1.5 volts high and 75 ns wide should now also be visible. This is the pulse received through the 15 cm fiber optic cable.
3. Adjust the "calibration delay" on the light transmitter to make the peaks of the two pulse coincide in time.
4. Readjust the oscilloscope's sweep/timebase scale to 20 ns and fine tune the calibration delay knob.

Measurement

1. Carefully loosen the fiber cinch nuts on LED D3 and detector D8. Remove the 15 cm length of fiber optic cable and replace it by the 20 meter length of cable.
2. Measure the time interval between the two pulses. This is the time required for the light to traverse the 20 m cable.
3. Calculate the speed of light in the cable. How does the speed of light in the cable compare with the speed of light in a vacuum?