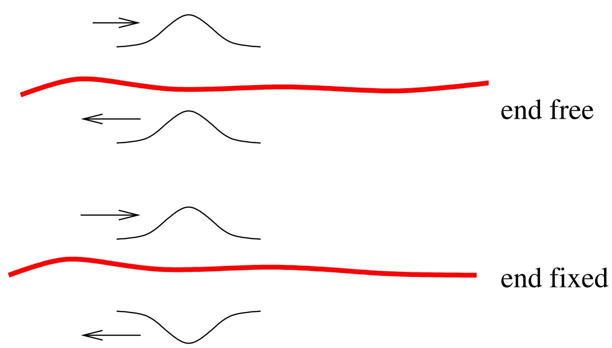
PHY 202/182 Lab Instructor notes
Lab 9: The speed of light
Spring 2004
This lab is supposed to have three parts. Presently, only get one part is working. I have written some notes on all three parts so I don't forget what I did.

0.1 Coax Cable

- This lab starts with an important demo. To do this, I used a clothesline rope attached to 2 m of fishing line at the far end. (Al Dainton says this demo is better done with a large slinky.) Make a Gaussian wave travel down the rope and note the amplitude of the reflected wave when the far end of the rope is fixed or is free.



  It takes some practice to produce a nice Gaussian wave on the rope.

- Explain that κ is kappa.
- Students have not directly estimated any errors in a long time. Remind the students that the estimate of error is *not* the difference between their velocity and c.
- Students will need multimeters to measure the resistance of the potentiometer.
- Students will need calipers (drawer 12).
- At the end of lab, make sure the DUTY is turned off on the older function generators.
- One important goal of the experiment is for the students to figure out *on their own* that they are seeing reflections from the end of the coax cable.
- At the end of the lab, disconnect all the wires and put away the multimeters.
- The duty knob on the signal generators should be turned off.

0.2 Fiber Optic Cable

Measure the speed of light in a fiber optic cable.

- A photodiode can be operated in "photo-voltaic mode" which maximizes sensitivity, but is slower. If there is a reverse bias voltage applied, the photodiode operates in "photo-conductive mode" which is much faster, but there is increased noise.

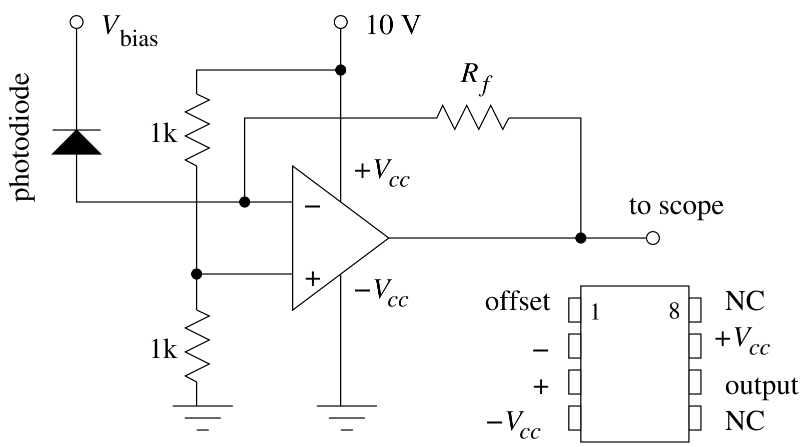
- I used a photodiodes and an IR LED scavenged from an "S. I. Tech Bit-Driver" 10 Mbit Ethernet transceiver, Model 2851. These were from Joe Hines. Since these transceivers are older, it is possible that the below identifications are wrong.

- The IR LED appears to be AMP part No. 259012–1 with ST-style connectors. Nominal operating current is 100 mA at about 1.4 V. Frequency is about 1300 nm.

- The photodiode appears to be AMP part No. 259013-1 with ST-style connector. The capacitance is about 1.5 pF and a responsivity of about 0.6 A/W.

- In the back room, there is a large spool of cable:
  50/125 μm single fiber, Type OFN (Belden T 227201). Outer jacket 0.150 in. or 3.8mm PVC. Attenuation is 3.0 dB/km at 850 nm wavelength. Unfortunately, Joe Hines was not able to terminate this fiber with the terminators he has here (maybe we can order terminators).

- I used a National Semiconductor CLC400 op-amp as the preamplifier for the photodiode.



In addition, there is a 0.01 μF capacitor connected to the "offset" pin and ground. Also there are 0.1 μF capacitors connected to ground and the 10 V power supply and V_{bias}. In choosing R_f, there is a tradeoff in speed versus gain. A choice of $R_f = 20\,\text{k}\Omega$ gives an RC time constant of about 10^{-7} s (which implies a capacitance of 5.8 pF). It is possible that driving the oscilloscope input affects this value. I found a bias voltage of about 5 V worked well, $V_{\text{bias}} = 10\,\text{V}$.

- Joe Hines had a spool of 250 ft. of cable, two fibers, which he terminated. For some reason unknown to us, the cable had 27 dB of attenuation relative to a short patch cable! At a frequency of 1 MHz, the signal was barely strong enough to be seen on the oscilloscope. (It may be that another op-amp is necessary for sufficient gain.)

0.3 Laser Ranging

This is a more electronic version of the classic speed of light experiment. The idea is to modulate a diode laser with the function generator, use a corner cube to reflect the signal and measure the reflected signal with a photodiode connected to a fast pre-amplifier. The time delay would be measured on the oscilloscope and the distance would be determined by surveying maps.

- The corner cube reflector from John Schaefer is not adequate. The mirrors are not flat enough and not well enough aligned.
- Note that the corner cube reflector does not need to be any bigger than half the size of the receiver lens, since we will not be any near the limiting beam size.
- Of the laser diodes, the "Arora" can be modulated at over 1 MHz. However, the adjustable lens on it does not work at all well; this will have to be removed before we can use it.
- The other, "California-Pacific Lab & Company," cannot be modulated at over 100 Hz. The optics on this model are OK, however.
- To complete the set-up, we will need some surveying maps, which can be obtained from Liljestrand, and some walkie-talkies, which can be obtained from Susan Moody.