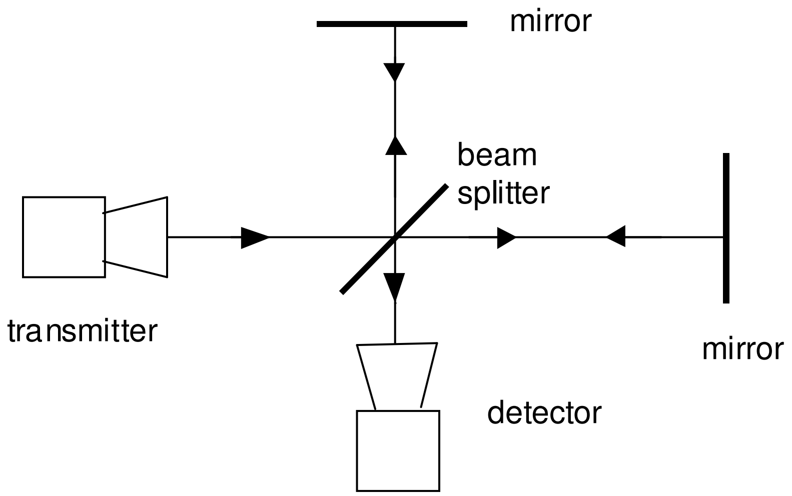
INTERFEROMETRY

The Michelson interferometer is famous for its use in the Michelson-Morley experiment. This experiment showed (to the surprise of Michelson and Morley themselves) ether did not exist and that th speed of light is the same in all inertial reference frames (which is a postulate of Einstein's Special Relativity). But the Michelson interferometer has many other uses, such as measuring small distances. Interferometry is actually responsible for the detecion of gravitational waves just this year! We will use a Michelson interferometer to measure the wavelength of microwaves produced by a microwave pyramidal horn antenna.

Safety: The intensity of our microwave transmitters is well within standard safety levels, but it is good practice to avoid unnecessary or close-range exposure (for example, don't stand in the microwave beam or look into the transmitter at close range when it's on). ***Pacemakers or other electronic medical devices may be affected by the microwave radiation. Please let me know if this is an issue.***

Background:

Microwave radiation from the source is divided into two beams by the partial reflector or "beam splitter" (for microwaves, a sheet of masonite works well for this purpose). The transmitted beam travels to one "mirror" (a flat metal plate) and the reflected beam travels to another mirror. These two beams then return to the partial reflector, and a portion of each travels to the detector, as shown.



Whether the beams "add up" or "cancel out" or do something in between when they recombine in going to the detector is determined by the total difference in distance the two beams travel from the point at which they split to the point at which they recombine. If the two beams travel the same distance, a "crest" of one wave train will arrive at the same time as a crest of the other wave train, and they will add up (constructive interference). In this case, the detector will indicate a large reading. If the difference in distance is a multiple of a wavelength of the radiation (λ, 2λ, 3λ, ...), the two waves will also arrive "in phase" and add up.

If the difference in distance is equal to $\lambda/2$, $3\lambda/2$, ... a crest of one wave will arrive at the same time as a trough in the other wave, and the two will tend to cancel (destructive interference). This will produce a low reading on the meter of the detector. (Stray radiation and the tendency of one beam to be stronger than the other usually keep the deflection of the meter from being exactly zero.)

Since each beam travels twice between the beam splitter and the mirror, moving one mirror a distance equal to $\lambda/4$ will change the path length by $\lambda/2$ and therefore should change constructive interference (a maximum) into destructive interference (a minimum) and vice versa. Thus, by measuring how far the mirror must move to change a maximum into a minimum, the wavelength of the radiation can be determined.

Microwaves are electromagnetic waves (light). Just like all waves, the speed of the wave is given by the equation $\boldsymbol{v = \lambda f}$. The velocity of light in a vacuum is well known $\boldsymbol{v = c = 3x10^8\ m/s}$. The frequency of the microwave source if given as 10.5 GHz and we can calculate the theoretical value of the wavelength.

We will also investigate the Law of Relflection and will observe refraction for microwaves.

Procedure:

Plug in the transmitter and turn on the receiver. The transmitter turns on as soon as it is plugged in, but the reciever is powered by 2-9 volt batteries and you must use the knob to turn it on. Face the trasmisstor twoard the reciever and see what effect rotating the transmitter horn relative to the receiver horn has. For best sensitivity, should the horns be aligned or at an angle to each other?

Adjust the Intensity dial on the receiver to see what effect it has. Move the transmitter and receiver closer to and then farther from each other and note what happens to the readings. What does the “10x” setting mean?

What does the Variable Sensitivity knob do? If recording transmitter readings is important, what happens if you change the Variable Sensitivity knob during an experiment?

Before we begin the Interferometry experiment, we will investigate refraction and the Law of Reflection. Set the multiplier on the reciever to 10 and turn the sensitivity knob all the way to the left.

Follow the instructions given by the TA.

Set up the Michelson Interferometer as shown. Place one of the mirrors at about the middle of its track and the other mirror about 40 cm from the beam splitter, which should be set at about 45˚. Adjust the angle of the first mirror to obtain a maximum reading on the detector meter. (If the needle goes off scale, or goes below half scale, change scales.) Then move the second mirror slowly away from the beam splitter until the meter reading is a minimum. Rotate the beam splitter slightly to see whether you can reduce the meter reading still further. Make a note of the scale; if you need to change the scale during an experiment, be sure to note that in your lab notebook. Move the receiver back and forth and notice the response of the meter.

Move the second mirror slowly away from the beam splitter, determining with as much precision as possible the positions of the mirror at which maxima and minima occur. Record at least 20 mirror positions for successive maxima, $x_1, x_2, x_3, ..., x_{20}$. Record these positions on your data sheet.

Data analysis:

The difference in the position vectors is related to the wavelength by the following equation:

$$\Delta x = m(\lambda/2)$$

-where $\Delta x = x_2 - x_1$ and m is the order number.

Your first position value, is your zero (i.e. it corresponds to the y-intercept). This is why on your data sheet this is listed as m = 0. This value essentially doesn't matter, as we only care about the relative change in position of the mirror.

To find the wavelength, use your data and the above equation to plot in Excel. Make sure to include all the necessary items on your graph and the linest values in your excel file.