Concepts in Physics
Lab 10: Microwave Optics

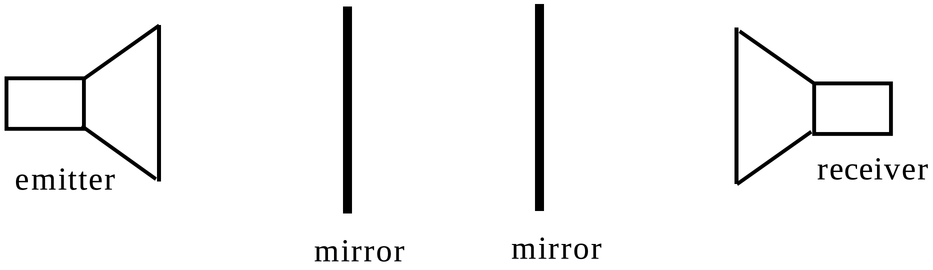
Peter Rolnick and Taner Edis

We will be dealing with microwaves, a kind of electromagnetic radiation with wavelengths of the order of a few centimeters—shorter than radio waves, longer than visible light. We have a source of microwaves, and a detector which shows the presence of microwaves by the deflection of a needle.

In this lab you will set up , and take and interpret data for, three different phenomena, each involving interference in some way. One thing I want you to notice is the interplay of theory and experiment. Physics is not simply looking at the world and writing down what we see. Without some theoretical background, it becomes very difficult to do an experiment. In your case, you experience some of the confusion a lack of a theory to guide you might cause—you're somewhat confused as to what's going on, and need to follow directions closely. Think of how much more lost you'd be if you didn't even have the simplified theoretical background I give you in these instructions.

Activity 1: Resonant cavity

You will set up two microwave "mirrors" facing each other (that is the cavity), and then you will "shine" some microwaves into that cavity. Most will be reflected, but some will get into the cavity. On the other side of the cavity some of the energy from the cavity will leak out and be detected by the detector: If twice the distance between the mirrors is equal to an integer number of wavelengths, then the waves formed as the microwaves bounce back and forth between the mirrors will reinforce each other, and you will have a *standing wave*. The energy density in the cavity is especially high when there is a standing wave, and thus the amount of microwave energy leaked out to the receiver will be particularly high. If you adjust the mirrors so that there is a standing wave, and then you move one mirror until you get another standing wave, then the distance the mirror moved must be half of a wavelength.



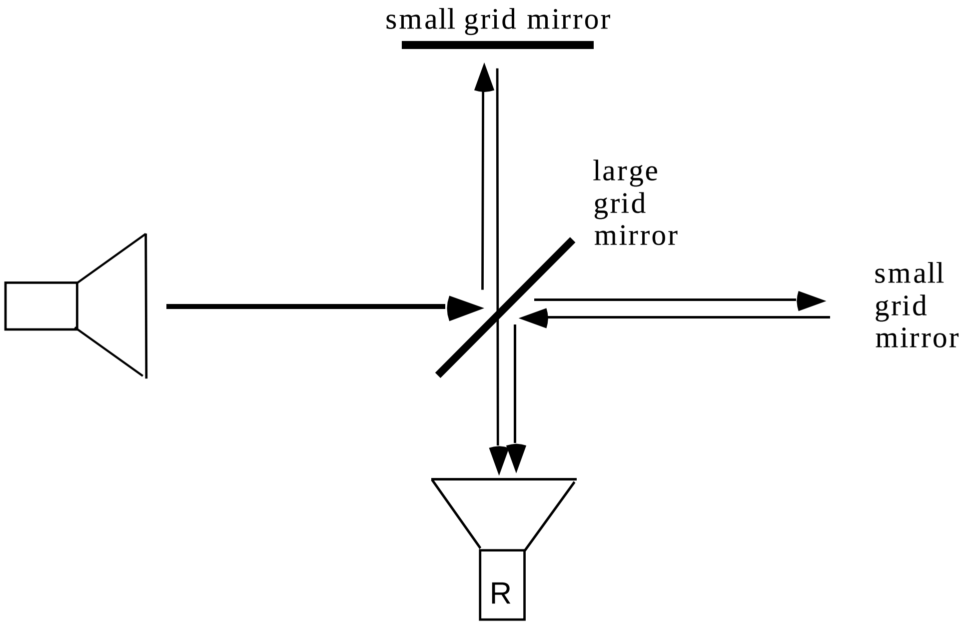
Using the set-up shown above, carefully measure the distance d you need to move one mirror for there to be 10 maxima (that is, 10 positions in which there is a strong standing wave). That distance must correspond to 5 wavelengths. *Note:* this kind of set up for capturing standing electromagnetic waves in a resonant cavity is called a Fabray-Perot Interferometer.

To hand in for Activity 1

- Distance d corresponding to 10 maxima.
- Expression used to find wavelength λ from d.
- Result for wavelength λ of the microwaves.

Activity 2: Interference

You are now going to set things up so that the initial beam is split and then recombined at the detector. If the two pieces into which the initial beam is split travel different distances, then, in general, they will not interfere constructively with each other when they recombine. But if the difference in distance traveled by one compared to the other is an integer number of wavelengths, then they will interfere constructively, and the detector will get a particularly strong signal.



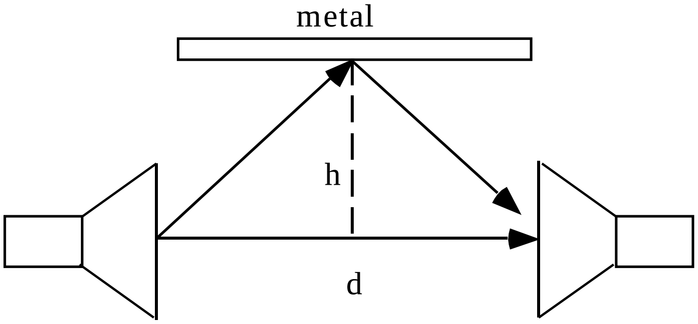
Use the following set-up: Move the small grid mirror on the right a distance d such that you count 10 maxima, and again that distance should correspond to 5 wavelengths, because for each distance you move, the signal must go out that much farther and back that much farther. *Note:* This kind of splitting and recombining interference device is called a Michelson Interferometer. If the wavelength of light used is very small, like visible light—λ_{visible} is about 10^{-7} m), then this instrument could be used to measure tiny distances very precisely.

To hand in for Activity 2

- Distance d corresponding to 10 maxima.
- Expression used to find wavelength λ from d.
- Result for wavelength λ of the microwaves.
- Comparison of your results from activities 1 and 2.

Activity 3: A model for radio signals

The ionosphere acts as a mirror for AM radio waves, and the ionosphere moves up and down. Sometimes a radio signal which bounces off the ionosphere interferes destructively with the original signal, and the result is that the radio station you are listening to fades out. We can make a model of this process by letting the emitter be the radio transmitter, letting the receiver be your radio, and letting the ionosphere be a large metal pan. Study the diagram. The waves will experience a phase shift of $\lambda/2$ (they will act as if they've traveled an extra half wavelength) upon reflection. So the signal at the receiver will be noticeably weak, due to destructive interference, if the path traveled by the "bounced" beam differs from the straight path by an integer number of wavelengths.



Let n be the number of wavelengths by which the two paths differ at destructive interference ($n = 1, 2, 3, \ldots$). With some geometry you can find

$$h = \frac{1}{2}\sqrt{n\lambda(n\lambda + 2d)}$$

Now set d at about 60 cm (but measure it precisely), and predict values of h at which you should get a particularly weak signal at the receiver for $n = 1$, 2 and 3. Test your predictions.

To hand in for Activity 3

- Measured value of d,
- Predicted values of $h_{\text{destructive}}$ for $n = 1$, 2 and 3,
- Experimentally determined values of $h_{\text{destructive}}$ for $n = 1$, 2 and 3.