Concepts in Physics

Lab 10: Microwave Optics

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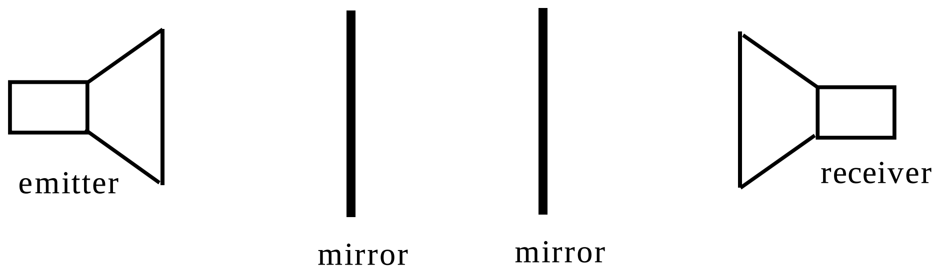
We will work with microwaves, electromagnetic radiation with wavelengths of a few centimeters—shorter than radio waves, longer than visible light. We have a source of microwaves, and a detector which shows the presence of microwaves by the deflection of a needle.

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 hus the amount of microwave energy leaked out to the receiver will be particularly high. The distance between successive locations of such an intense response is half of a wavelength.



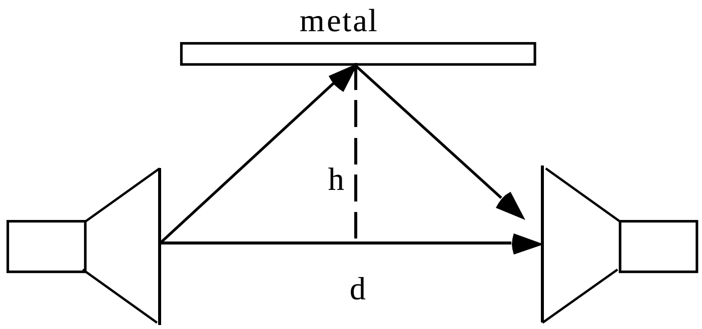
Using the set-up shown above, carefully measure the distance d you need to move one mirror for there to be 10 maxima (that is, 10 positions in which there is a strong standing wave). That distance is 5 wavelengths.

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: 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.



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 2

- 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.

Activity 3: Double-slit interference

You will perform your own version of the double-slit experiment, using the microwave source and detector, and the double slit screen in your equipment box.

If you were to look it up in a textbook, you would find that the bright fringes (constructive interference) will take place when

$$d \sin\theta_m = m\lambda \qquad m = 0, \pm 1, \pm 2, \ldots$$

You will be able to measure the central maximum ($m = 0$), and the first maxima ($m = \pm 1$), but probably no more.

I will set your experiment up; when you're ready, call me over.

You will measure the angle θ. Record the intensity I at various values of θ. Make a graph of how I depends on θ. (Don't worry about units for I, because we only care about relative intensities, not absolute values.)

Note that d in this activity has nothing to do with distances involving the source or detector. Instead, d is the distance between the *centers* of the two slits.

Remember that you have already measured λ before. Therefore check if your experimental location of the $m = \pm 1$ intensity peaks fit your theoretical predictions.

To hand in for Activity 3

- Predictions of your θ values for $m = \pm 1$,
- Graph of I vs θ,
- Experimental values for θ at $m = \pm 1$ (the peak locations in your graph).
- A comparison (percent difference) of your experimental and theoretical results.