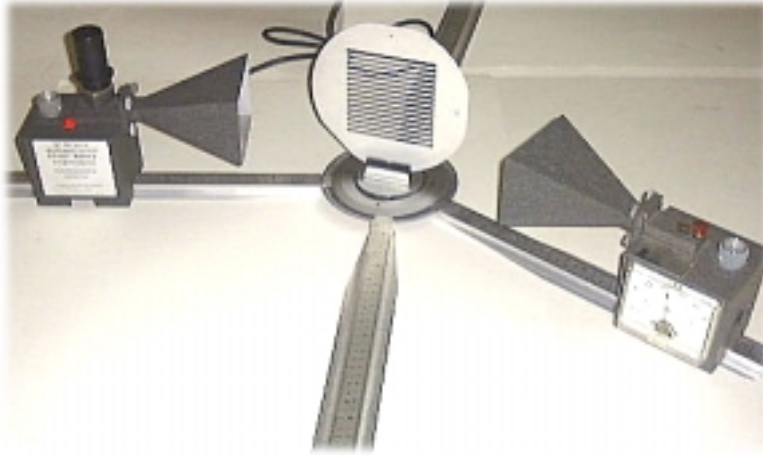


# MICROWAVE OPTICS

## REFERENCES

Most Introductory Physics texts (e.g. A. Halliday and R. Resnick, *Physics*; M. Sternheim and J. Kane, *General Physics*).

## INTRODUCTION



The Microwave Optics set is essentially a sophisticated toy that can be employed to illustrate - in a qualitative and often quantitative fashion - many of the phenomena associated with wave propagation in general and electromagnetic wave propagation (including polarization) in particular.

In this experiment you should make qualitative observations to the best of your (or the apparatus') ability. Do not get frustrated by the optics set's inadequacies - rather you should understand its limitations, obtaining insights and understanding of wave phenomena and appreciating where the apparatus' illustration of the phenomenon under study is limited.

The text below describes nine possible experiments you can do with the apparatus. Your work will be counted as either one or two weights according to the following guidelines:

One weight: Experiments 1-3

Two weights: Experiments 1-6; Three weights: all experiments

## THE APPARATUS

Figure 1 shows the basic components of the set, the transmitter, with its klystron oscillator producing microwaves of approximately 3 cm wavelength, the receiver, the antenna horn, and various positioning devices and slides.

The initial set-up of the apparatus is done by placing the receiver and transmitter (with attached horns) facing each other on their slides, with the ends of the horns about 20 cm apart. Set the gain control on the receiver at about 3 divisions, let the klystron (transmitter) warm up for at least two minutes. *Very slowly* adjust the repeller tuning knob on the transmitter to obtain maximum power as read on the receiver meter. You will find various power peaks. For your experiment, use the peak that gives the highest reading. This tuning must be done very carefully. It should be checked for *minor* adjustment before each experiment.

## MICROWAVES

Note that while taking readings it is important, in order to avoid affecting your data, that you avoid placing your hand or any other object within the region of the microwave field.

Also note that the meter on the receiver is very heavily damped in order to reduce the effects of extraneous electrical noise. We thus recommend that all measurements in which apparatus is moved or positioned be made by moving the components *very slowly*.

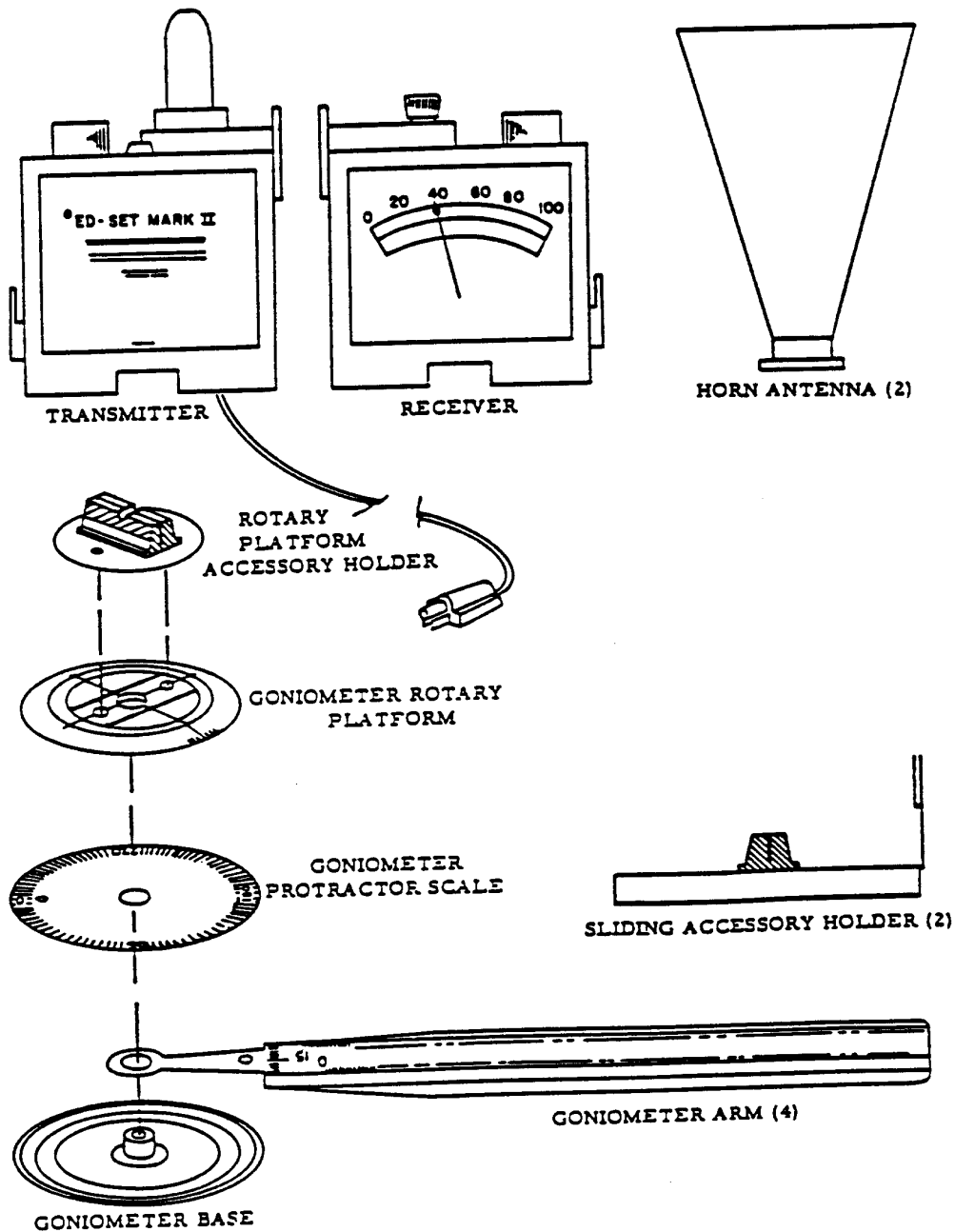


Figure 1.

Figure 2 shows the various masks, reflectors, refractors, slits and grids that you have available to mount in the accessory holder for your various experiments.

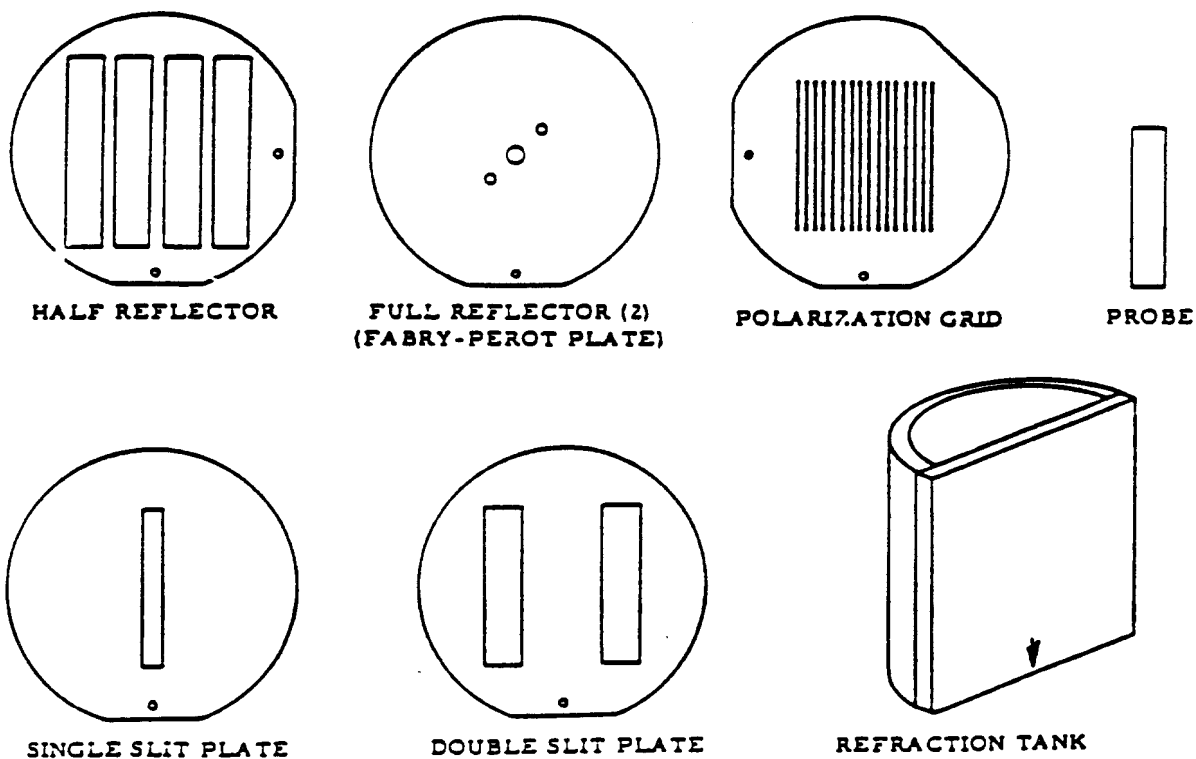


Figure 2.

## THE EXPERIMENTS

### 1. Absorption

Placing the receiver and transmitter (with attached horns) on their slides, facing each other with the ends of the horns about 20 cm apart, set the gain control on the receiver to obtain a reading of 100 on the receiver meter. Place, on the rotary platform, an absorber such as a text book with the cover at an angle of 45 degrees to the line between the transmitter and receiver. Note the receiver reading, giving the transmitted power. Now move the receiver to the 90 degree position to maximize reflection off the book cover into the receiver and observe the reflected powers. The incident (original) power level minus the sum of the transmitted and reflected power is the absorbed power. The absorption is the ratio of the absorbed power to the incident power. You may also try other absorbers such as wood, dry-wall board, cellulose sponge, glass plates, plastics, etc.

The measurements in this section can only be very qualitative.

## 2. Polarization

Arranging the apparatus as in the previous section, but with the polarization grid placed in a plane perpendicular to the beam in the rotary platform accessory holder, rotate the grid about an axis perpendicular to its plane and observe the receiver readings. The klystron and horn produce electromagnetic waves with the electric vector polarized vertically. Can you explain how the polarization grid works? Interpret your observations in the light of what you know about polarization of light.

## 3. Law of Reflection

Arrange the apparatus as in Figure 3. Rotate the rotary platform and find the position for peak reading. Repeat this procedure using different angles between receiver and transmitter. For one or two angles, use the polarizing grid in place of the full reflector, with the grid turned first with its slots horizontal, the with its slots vertical. Knowing what you now do about the direction of polarization of the electric vector for these microwaves, what do you conclude?

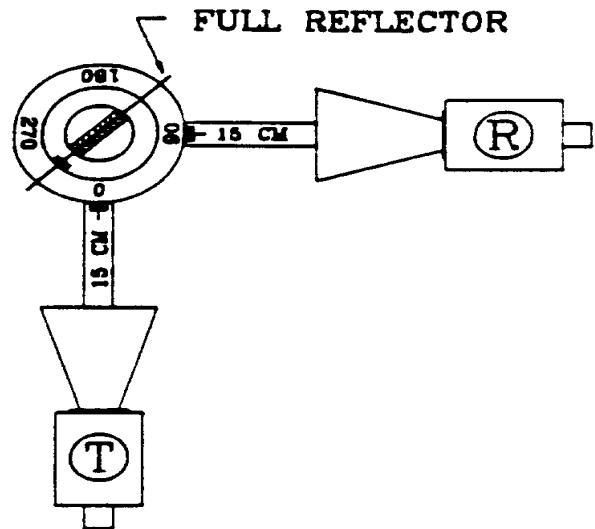


Figure 3.

## 4. Standing Waves

Arrange the apparatus as in Figure 4. This arrangement will create a standing wave pattern between the transmitter and the full reflector. A portion of the wave pattern is picked up by the probe plate and reflected to the receiver. As you move the full reflector you can observe the variations of the signal being picked up by the receiver. You may plot a graph of the standing wave intensity in terms of reflector position. You may actually find the positions of the maxima and minima most useful for determining the wavelength,  $\lambda$ .

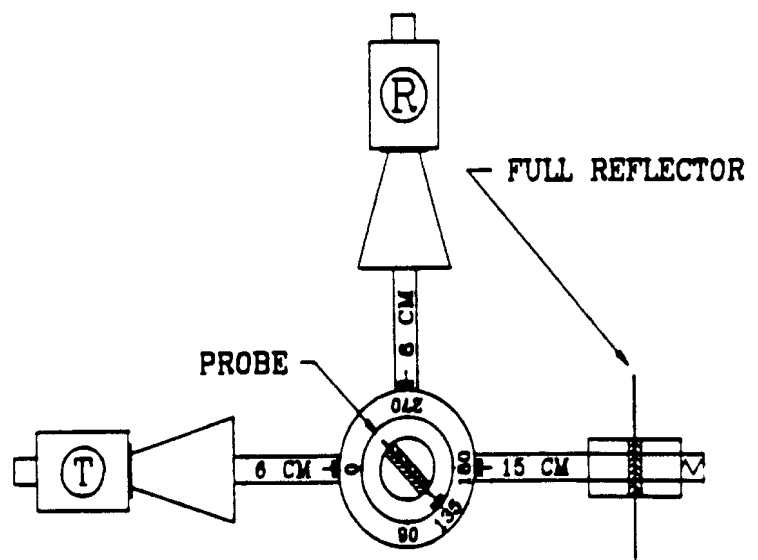


Figure 4.

## 5. Michelson Interferometer

Arrange the apparatus as in Figure 5. Optimize the setup for sharpest nulls by removing the full reflectors from the two sliding accessory holders and by slightly changing the positions of the transmitter and receiver from their 10 cm marks until a maximum reading is obtained. Replace the two full reflectors and position the 270 degree full reflector for a minimum reading on the meter. Sharpen this null by adjusting the 180 degree full reflector. Adjusting the 270 degree full reflector will now give deep nulls.

The free space wavelength can now be determined by measuring the distance travelled by the 270 degree full reflector between nulls. This distance is equal to  $\frac{1}{2}$  wavelength in free space.

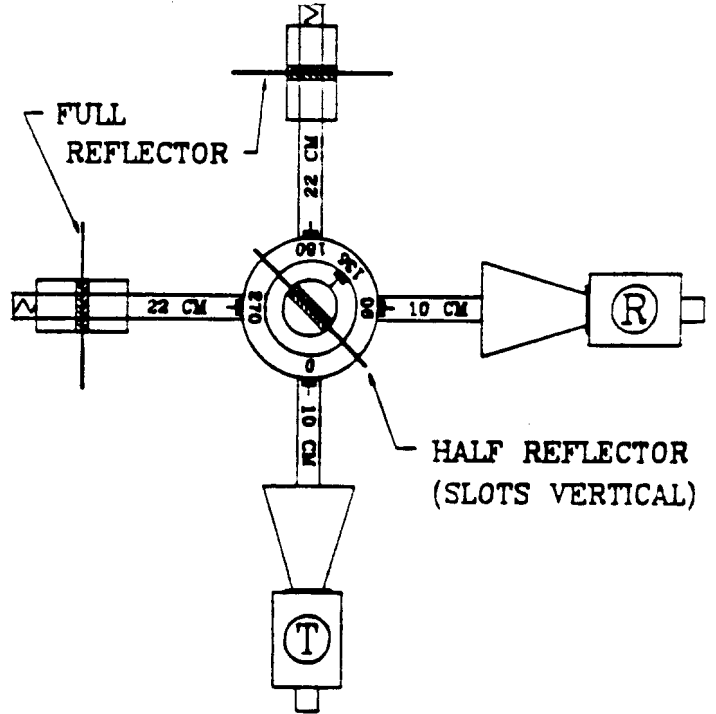


Figure 5.

In addition you may measure the index of refraction of low loss materials in this sheet form by placing the sheet in a vertical position between the 270 degree full reflector and the half reflector. Subject to minor error caused by multiple reflections within the sample, the index of refraction can be calculated using

$$\eta = 1 + \frac{\Delta}{d}$$

where  $\eta$  is the index of refraction,  $\Delta$  is the full reflector movement required to restore the original null after insertion of the material, and  $d$  is the thickness of the sample.

## 6. Thickness of a Thin Film

Arrange the apparatus as in Figure 6. Using the positioning attachment, move the full reflector away from the axis to produce sharp nulls and peaks in the receiver readings. By noting the distance between the full reflector and the half reflector at null points, it will be observed that nulls occur when the distance between the full reflector and the half reflector are multiples of half wavelengths of the microwaves. Similarly peaks occur when separation distances are multiples of odd quarter wavelengths. This is analogous to optical thin-film interference effects which produce dark and light bands in the reflected light of a single colour. In this case the spacing between the half reflector and the full reflector is comparable to the thickness of the thin film.

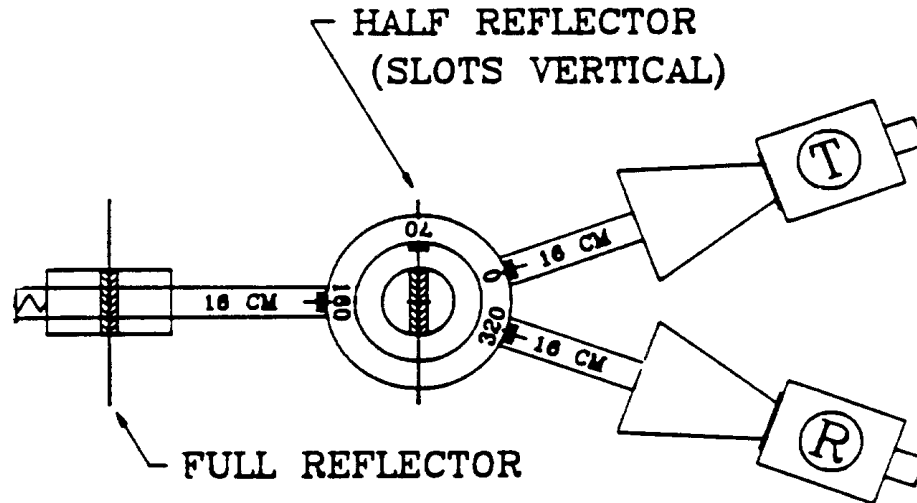


Figure 6.

## 7. Single Slit Diffraction

Placing the receiver and transmitter (with attached horns) on their slides, facing each other with the transmitter horn tight up against the single slit plate and the receiver horn as close to the slit as you can put it, but far enough away that you can swing the receiver arm through a considerable angle, measure the diffraction pattern of the single slit (*i.e.*, received intensity as a function of angle of receiver). How does the angle of the first minimum or the second maximum compare to theory? You might consider plotting the intensity *versus* angle results on polar or linear graph paper.

Repeat this measurement, but with the slit removed, so that the transmitter horn opening is essentially a single slit. In this case you will only be able to observe the central maximum and the first minimum. How does the position of the first minimum compare to theory? How does the angular width of the beam from the horn relate to the width of the horn?

## 8. Double Slit Diffraction

Repeat the measurement of part 7, with the double slit plate substituted for the single slit plate. Compare the positions of the several maxima you obtain with the theoretical prediction for a double slit of slit spacing equal to the spacing between centres of the slots. Try making measurements with the receiver close-up as in part 7, and with the receiver placed near the end of its slide arm.

## 9. Index of Refraction

Arrange the apparatus as shown in Figure 7. Fill the refraction tank with the material to be measured (polyethylene beads.) Set the tank to select the angle of incidence and then rotate the receiver arm to obtain maximum received signal to find the angle of refraction. Do this for several angles of incidence and deduce the refractive index.

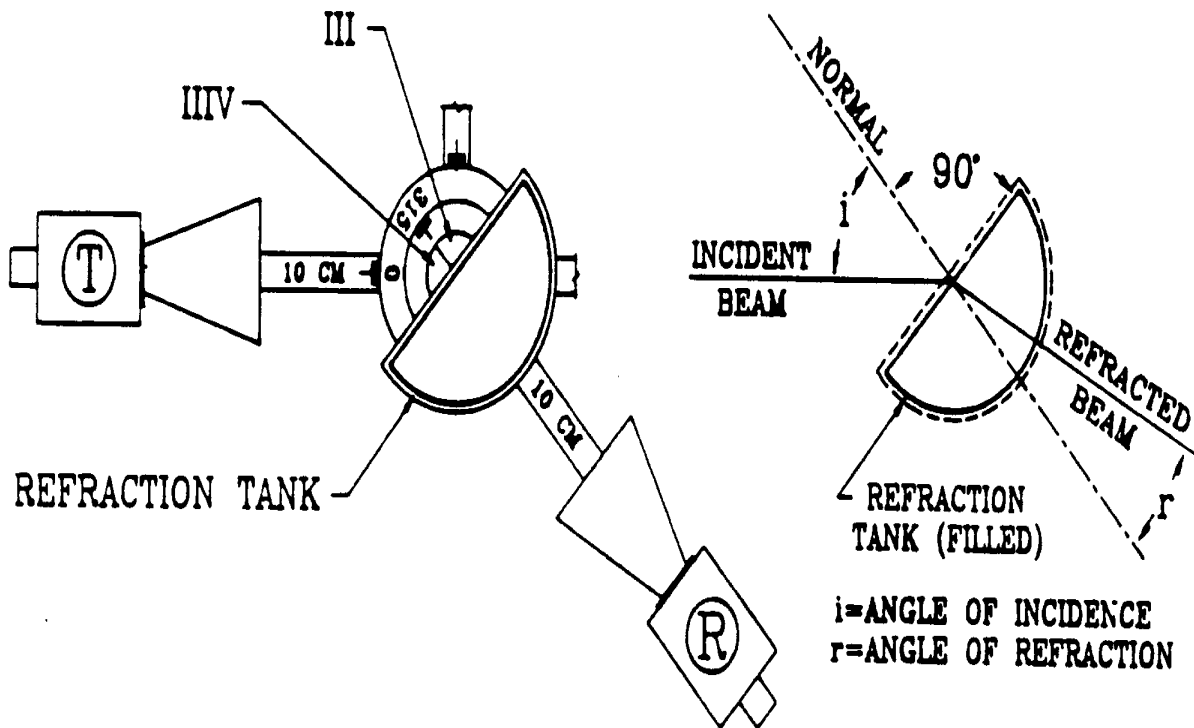


Figure 7.

(ch - 1978, jbv - 1988)