Microwave Optics: Bragg Diffraction

Equipment Needed:

From the large microwave optics box:

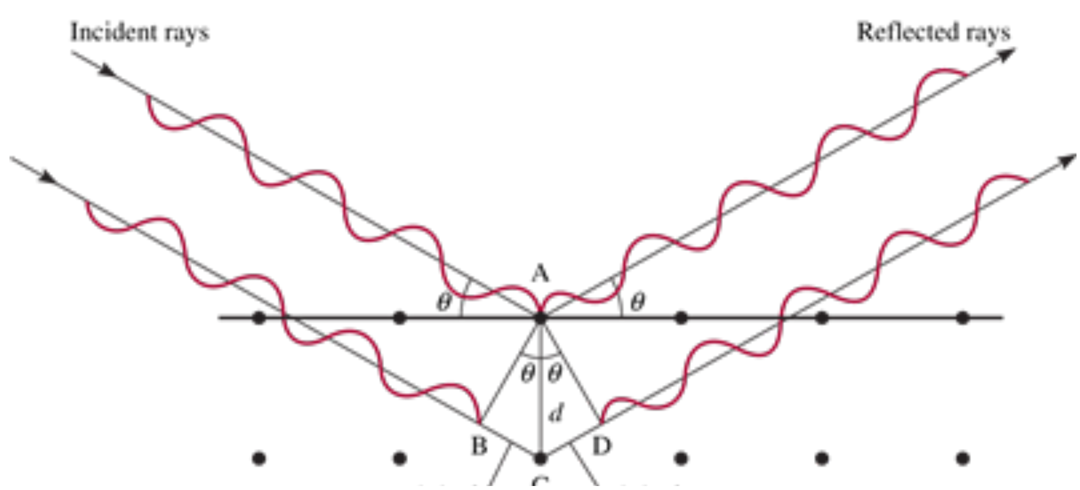
Goniometer and rails (embedded in the top piece of foam)
Large mounts and mounting screws
Transmitter
Receiver
Rotating table (made mostly of foam, do not separate it from its metal base)
Provided separately: Cubic Lattice (foam and metal)

Purpose and Background

Bragg's Law provides a powerful tool for investigating crystal structure by relating the interplanar spacings in the crystal to the scattering angles of incident x-rays. In this experiment, you will investigate Bragg's Law on a macroscopic scale using microwaves and a cubic "crystal" consisting of 10-mm metal spheres embedded in an ethafoam cube.

Before performing this experiment, you should understand the theory behind Bragg Diffraction. In particular, you should understand the two criteria that must be met for a wave to be diffracted from a crystal into a particular angle. Namely, there is a plane of atoms in the crystal oriented with respect to the incident wave, such that:

1. **The angle of incidence equals the angle of reflection, and**
2. **Bragg's equation, $2d\sin\vartheta = n\lambda$, is satisfied; where d is the spacing between the diffracting planes, ϑ is the *grazing angle* of the incident wave, n is an integer, and λ is the wavelength of the radiation.** As seen below, the wave reflected from the 2^{nd} plane travels $2d\sin\vartheta$ farther than the first wave so the two reflected waves are in phase when this distance is an integer multiple of the wavelength.



Procedure

1. Arrange the equipment as shown in Figure 12.1.
Make sure the transmitter and receiver are the **same polarity** (the rectangular opening is oriented in the same direction)**.**

IMPORTANT: Reflections from nearby objects, including the table top, can affect the results of your microwave experiments. To reduce the effects of extraneous reflections, keep your experiment table **clear of all objects, especially metal objects,** other than those components required for the current experiment.

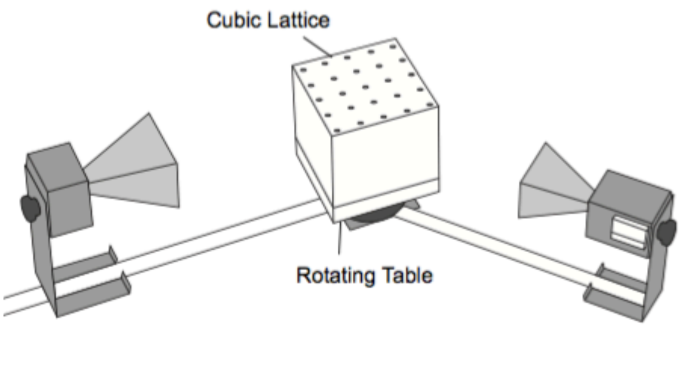
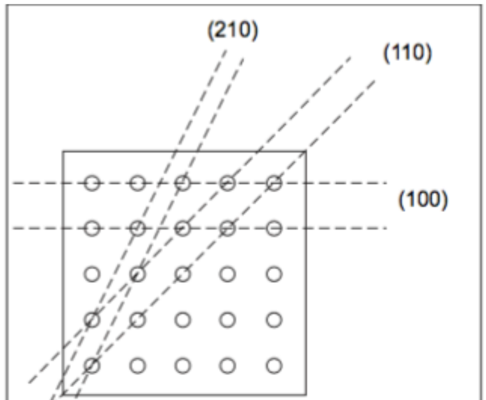


Figure 12.1: Equipment Setup

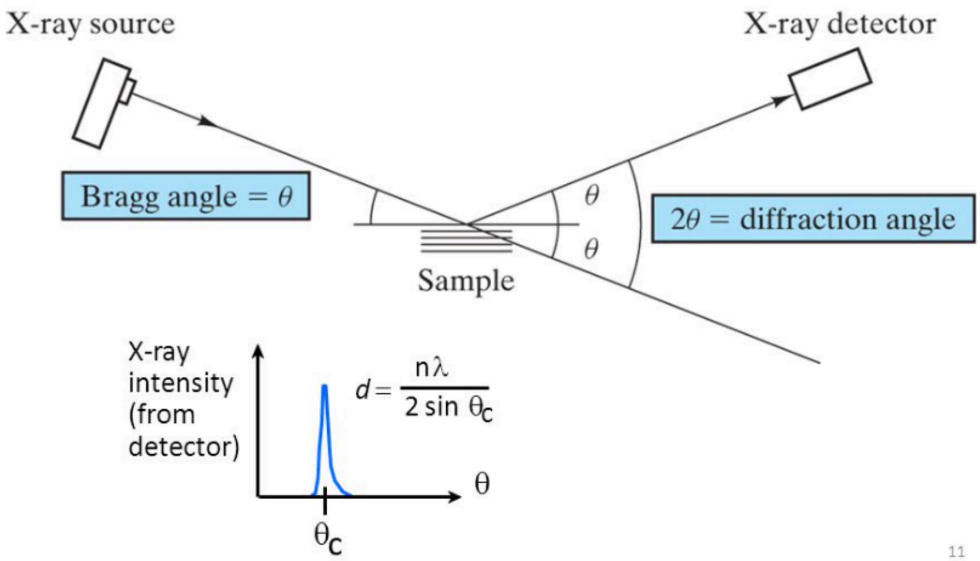


: Figure 12.2: "Atomic" Planes of the Bragg Crystal

2. Notice the three families of planes indicated in **Figure 12.2**. (The designations (100), (110), and (210) are the Miller indices for these sets of planes.) **Measure** the spacing between the metal spheres in your 'crystal' and **calculate** the expected locations (grazing angles) of the n=1 and n=2 peaks for the 100 plane and n=1 peak for the 110 plane. The wavelength of the microwave radiation is 2.85cm.

3. Adjust the Transmitter and Receiver so that they directly face each other. Align the crystal so that the (100) planes are parallel to the incident microwave beam. Adjust the Receiver controls to provide a readable signal. **Record the meter reading.**

4. Rotate the crystal (with the rotating table) one degree clockwise and the Rotatable Goniometer arm two degrees clockwise. Record the grazing angle of the incident beam and the meter reading. (The grazing angle (Bragg angle) is the complement of the angle of incidence. It is measured with respect to the plane under investigation, NOT the face of the cube, see below.)



4. Continue in this manner, **rotating the Goniometer arm two degrees for every one degree rotation of the crystal**. Record the grazing angle and meter reading at each position.

Note, you will likely need to adjust the sensitivity of the receiver once you move off-axis as, as the n=1 peak is much smaller than the n=0 (on axis) signal, and the n=2 peak is even weaker than the n=1 peak. If you need to do this be sure to indicate that in your data. You may want to position the 'crystal' and receiver at one of the expected off-axis peaks when making adjustments, and once the signal is strong enough go back and record the data for that peak. The strength of the signal can be increased by turning the knobs on the receiver, adjusting the position of transmitter and receiver, and sometimes changing the polarity of the transmitter and receiver (but making sure they are still the same polarity as each other).

5.Repeat this procedure for the n=1 peak of the (110) plane.

6.For both the (100) and (110) planes, plot the relative intensity of the diffracted signal as a function of the grazing angle of the incident beam. At what angles do definite peaks for the diffracted intensity occur for each plane?

7.Using your data, the known wavelength of the microwave radiation (2.85 cm), and Bragg's Law, calculate the **spacing between the 'atoms' of the Bragg Crystal**. Calculate a spacing for each peak: n=1 and n=2 of the (100) plane and n=1 of the (110) plane and **average the three values**. Note that the spacing you calculate using the Bragg equation for the (110) plane is half the diagonal of the atomic spacing.

8.Compare the average atomic spacing you calculated above with the spacing you measured between the metal spheres, calculate the percent error, and comment on potential error sources.

9.Suppose you did not know beforehand the orientation of the "inter-atomic planes" in the crystal. How would this affect the complexity of the experiment? How would you go about locating the planes?

PLEASE MAKE SURE YOU HAVE TURNED OFF THE RECEIVER BEFORE PUTTING THE MICROWAVE OPTICS KIT BACK INTO THE BOX.