PHY 252 Lab 6: Bragg Scattering of Microwaves

Fall 2009, version 2

1 Purpose

In this experiment, we will study the scattering of microwaves from a "crystal" made up of ball bearings embedded in styrofoam. We will find diffraction maxima that are similar in form to those encountered in Bragg scattering of X-rays from crystal lattices (see Fig. 1), except that of course our "crystal" is in 3D (see Fig. 2). In the case when all atoms are in a simple cubic form with lattice constant a, the distance between planes becomes

$$d = \frac{a}{\sqrt{\ell^2 + m^2 + n^2}} \tag{1}$$

where the Miller indices for the crystal are $\langle \ell m n \rangle$.

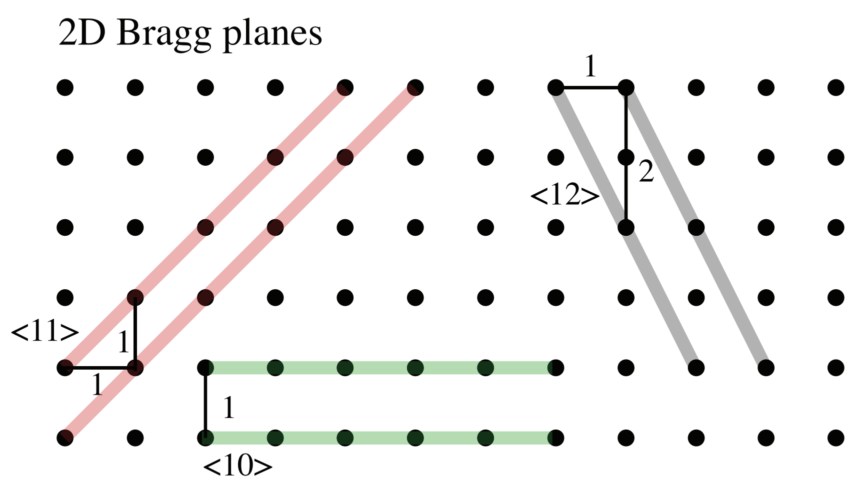
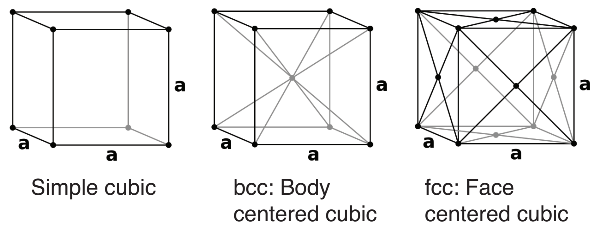


Figure 1: Bragg planes in a 2D crystal lattice. The coherent superposition of scattering from individual atoms leads to the appearance of scattering planes within a crystal. These planes are indexed by the number of atomic steps one has to go to get to the next lattice plane. In this diagram, the 2D steps are $\langle 10 \rangle$, $\langle 11 \rangle$, and $\langle 12 \rangle$. The extension to 3D is straightforward.



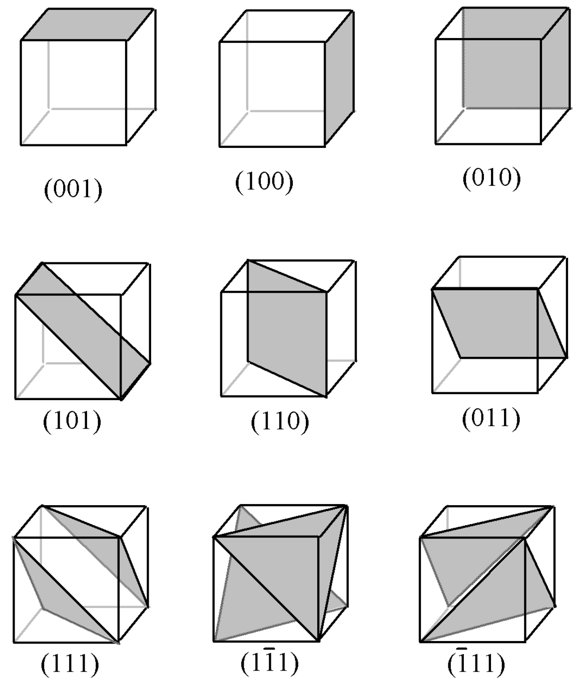


Figure 2: Illustration of cubic crystal types (above), and Miller indices $\langle \ell mn \rangle$ in a simple cubic crystal (right).

2 Procedure

1. Assuming that the atoms are arranged in a face centered cubic lattice with constant spacing a, figure out the d spacing between crystal planes for the $\langle 100 \rangle$, $\langle 110 \rangle$, and $\langle 111 \rangle$ planes as a fraction of a.

2. Set up the microwave transmitter and receiver on a meter stick so that the horn antennas face each other. Turn on the transmitter and turn up the receiver sensitivity to about half-scale. Tune the transmitter's klystron for a maximum response from the receiver. As you perform the experiment, periodically check the tuning. Be careful with the apparatus, as the klystron can get quite hot.

3. In some sense you have defined an optical cavity between the receiver and the transmitter, so that when you have an integer number of half-waves between the two ($n\lambda/2$) you will see intensity minima in the receiver. Use this to determine the wavelength, by slowly moving the receiver straight out along the meter stick measuring the distance between successive intensity minima. Take readings over a wide range of distances to minimize the error.

4. Now place the transmitter and receiver on the arms of the goniometer. Systematically look for Bragg scattering from the "crystal" planes, seeking in particular the $\langle 100 \rangle$, $\langle 110 \rangle$, and $\langle 111 \rangle$ planes from a a simple cubic lattice. In each case, verify the Bragg formula

$$2d \sin\theta = n\lambda. \tag{2}$$

5. Determine the ball bearing spacing a from your scattering results and compare with directly measured values.