Modern Physics Lab

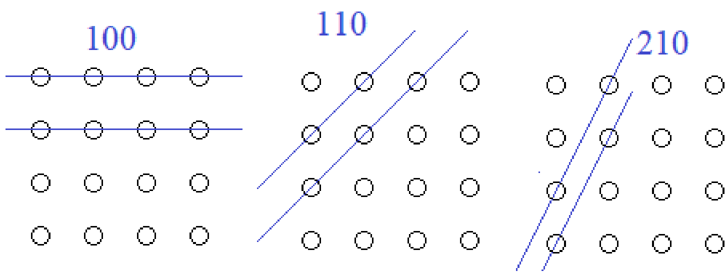
Bragg Diffraction

Introduction: William Bragg and his son Lawrence discovered that crystalline solids reflected X-rays with high intensities at certain glancing angles. These results provided a tool for investigating crystal structure by relating the inter-plane distances in the crystal to the scattering angles of incident x-rays.

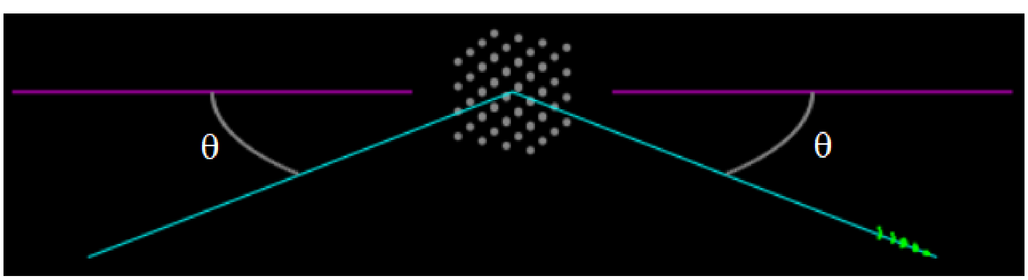
In our experiment, we will investigate a scaled up version of their experiment. Instead of X-rays we will use microwaves with wavelengths of the order of centimeters, not Angstroms, and the crystal will be a macroscopic arrangement of 64 steel balls in a simple cubic structure.

Theory:

Consider the crystal planes separated by a distance *d*. This will depend of how the crystal is oriented. We can easily explore the 100, 110 and 210 configurations (these numbers are called Miller indices) by facing the crystal directly, at 45 degrees and at 27 degrees. You might also want to try the 111 configuration (if you are adventurous enough).
The image below illustrates these planes for the simple cubic lattice of our set-up:



In the experiment we will measure intensity of the diffracted microwaves as a function of grazing angle. Notice that this is the complement of the conventional incident angle that you used in Physics II.



The peaks in the Bragg diffraction occur when the reflection from the planes interfere constructively, which happens when the extra distance traveled by the waves is a multiple of the wavelength according to the equation:

$$2d\sin\theta = n\lambda$$

Goals: The experimenters will learn how to put together a microwave emitter and a detector with oscilloscope for better accuracy in the measurements. They will also observe the peaks in the diffraction intensity due to constructive interference of reflections from planes.

Recall the equations constructive interference learned in Physics II.
Learn the meaning of the Miller indices.

Equipment:

Microwave emitter with external power supply.
Microwave detector with needle meter and output terminals.
Oscilloscope to connect to the detector and observe the signal.
Styrofoam cube with 64 embedded steel balls in a simple cubic lattice.

Experiment 1: *measure diffraction intensity as a function of grazing angle.*

Place the emitter and detector on the arms of the apparatus. Try to align them as best as you can.
Place the crystal in the center of the table with the selected configuration (100, 110 or 210).
Connect the oscilloscope to the detector with appropriate cables. Select voltage range, sweep frequency and trigger mode to observe the signal clearly, so you can get good precision.

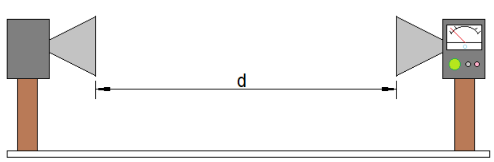
Record intensity vs angle. You can decide what the best way of doing this is. Perhaps every 2 degrees in the range that is available. Decide if you want to change the distance between the crystal and the arms and do other(s) run(s).

Record the distance between balls which we call *a*. This is to calculate the expected peak positions according to Bragg's diffraction equation:

$$\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$$

For the 100 configuration $d = a$, for 110, $d = a/\sqrt{2}$ and for 210, $d = a/\sqrt{5}$.

Experiment 2: *measuring wavelength*



For your calculations you will need the wavelength of the microwaves. Even though you can find the nominal value from the manufacturer (c/frequency) it is better if we determine it by an experiment. In the configuration shown above we can measure the intensity as a function of distance between the emitter and detector. The value will change due to the distance *d* between detector and emitter, but also due to the partial reflection from the horns. Local peaks should happen at distances that are multiples of lambda/2 since then the reflections will add constructively.

Analysis:

Plot the intensities as function of grazing angle for the experiments that you have done and superimpose them with the expected peaks from Bragg's law.
Are they where you expected?
Can you explain discrepancies in the results?

Here is an example of what is expected for a typical experiment with the 100 configuration showing three large peaks at angles of 18°, 39° and 72°approximately, while there are other smaller peaks as well.