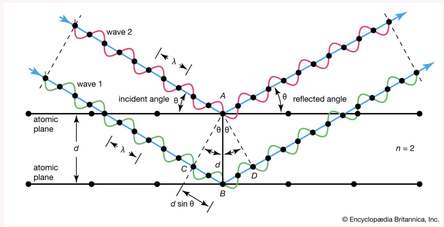
Different Types of Diffraction and Their Implications

Joshua Dupuis[2], Kevin O'Shea[1], Harold Metcalf [1]

[1] Department of Physics and Astronomy , Stony Brook University, Stony Brook, NY, 11794, USA.
[2]East Lansing High School, East Lansing, Mi, 48823, USA

What is diffraction?

Diffraction is when waves, particularly waves of light, bounce/scatter off of objects. In my case, the object in question was either the atoms in a crystal lattice or slits in a diffraction grating.



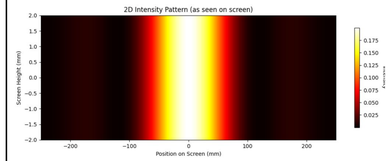
Optical N-Slit Diffraction

Slit diffraction and constructive interference:

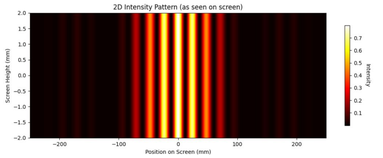
Slit diffraction and constructive interference occur when waves align in phase, causing their amplitudes to add together, similar to ripples in a pond. This alignment results in constructive interference, while out-of-phase waves lead to destructive interference, where crests and troughs cancel each other out. Together, these effects produce distinct lines on a screen during a slit experiment.

ALL DATA BELOW IS SIMULATED, each intensity pattern was made using a simulated laser with a wavelength of 600nm, a slit width of 5μm, and a slit separation of 25μm

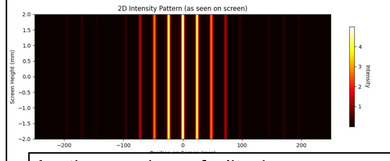
1 Slit Diffraction Pattern



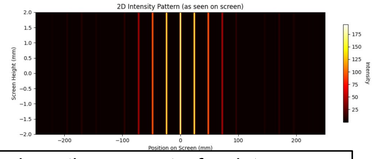
2 slit diffraction pattern



5 slit diffraction pattern



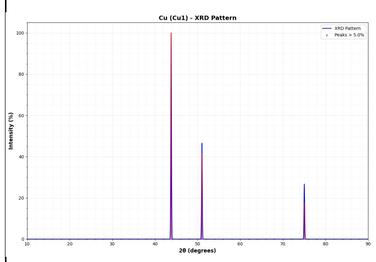
100 slit diffraction pattern



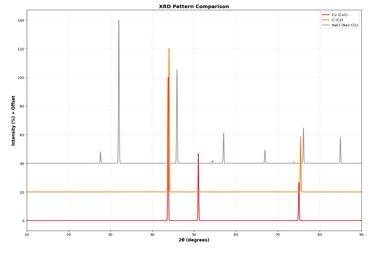
As the number of slits increases, so does the amount of point sources, which then causes more destructive interference, and more intensified constructive interference, leading to sharper lines in addition to smaller, more faint, secondary maxima. In essence, the light that would have "bled" out to the sides is canceled out by more light waves. We consider every point on a wavefront can be considered a source of secondary wavelets, or, in other words, a point source.

X-Ray Diffraction

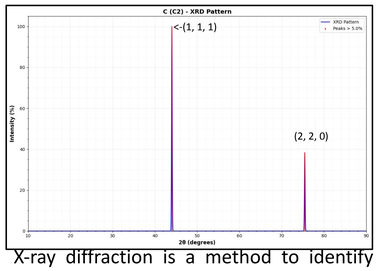
XRD Pattern of Copper



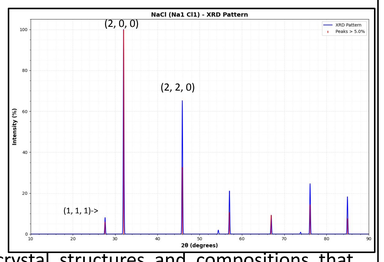
Comparison of Copper, Diamond, and Rock Salt XRD Patterns



XRD Pattern of Diamond



XRD Pattern of Rock Salt

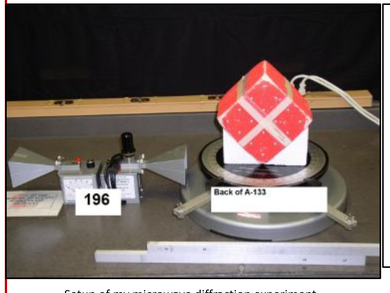


X-ray diffraction is a method to identify crystal structures and compositions that utilizes the process of bragg scattering to as such. Crystal compositions and structures are identified using the resultant diffraction patterns of scattered x-rays.

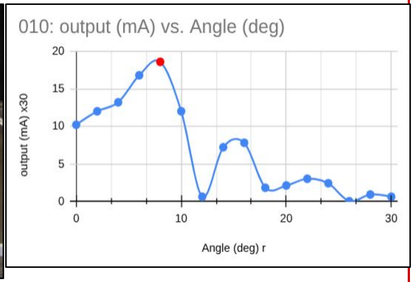
Constructive interference in XRD occurs when the spacing between atoms within a crystal lattice corresponds to the wavelength of the incident radiation.

Bragg Scattering & Experiment

To simulate bragg scattering, I used a microwave emitter, a microwave receiver, a turntable, and a styrofoam block with steel ball bearings in the middle to simulate the crystal lattice. I then altered the angles at which both the receiver and emitter were positioned relative to the styrofoam block with the ball bearings to gauge the angles that would produce constructive interference, and thus relative maxima.



Setup of my microwave diffraction experiment



Data showing peaks at 010 miller index from experiment

Explanations & Equations

Miller Indices

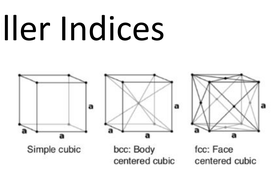
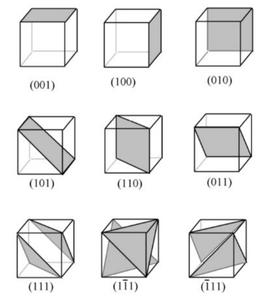


Figure 2: Illustration of cubic crystal types (above), and Miller indices $\langle lmn \rangle$ in a simple cubic crystal (right).



Miller indices are a mathematical way to categorize different orientations of crystals to get a relative different distance (d) in between the planes of atoms in the crystal, which in turn dictates the angles at which constructive interference can occur.

$$d = \frac{a}{\sqrt{l^2 + m^2 + n^2}} \qquad 2d \sin\theta = n\lambda$$

Different miller indices result in different intensities/higher or lower peaks when hit with rays of light, as displayed in the images to the left

Summary

There are many different types of diffraction, each of which can give critical insight into different phenomena, and help us gain a better understanding of our universe as a whole.

- N slit diffraction helps us understand the properties of light and waves in general
- X-Ray Diffraction is actively used to determine crystal composition and crystal structure
- Bragg scattering is the fundamental phenomena behind all types of diffraction

Acknowledgements

I would like to thank both the **Simons Foundation** and the **Laser Teaching Center** for providing me with this opportunity.

SIMONS FOUNDATION

Welcome to the Laser Center