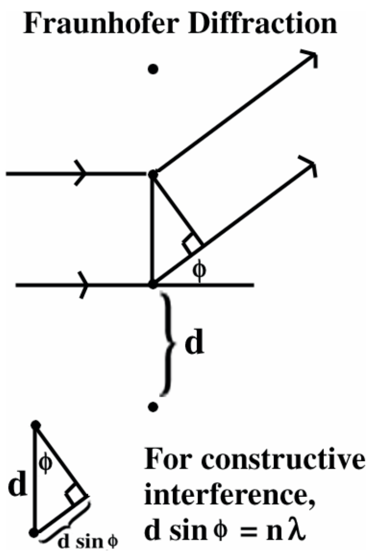
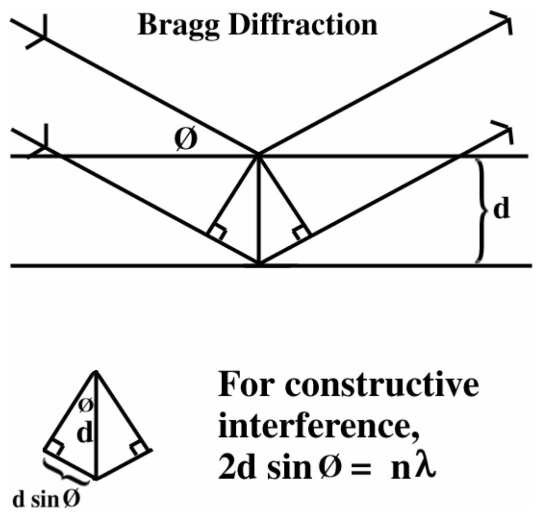
Spring 2009

CHEM 208
Lab 2: Optical Diffraction

Introduction

The optical diffraction of monochromatic, coherent (laser) light from a 1 or 2 dimensional grating (Fraunhofer diffraction) is directly analogous to X-ray diffraction by crystals (Bragg diffraction).





When waves pass through a periodic pattern where the repeat distance of the pattern is similar to the wavelength of the waves, diffraction occurs. Observation of diffraction patterns from beams of electrons, neutrons or X-rays passing through crystalline solids thus serves as evidence both for the wave nature of those beams and for the atomic nature of the crystalline solids. The symmetry and spacing of the periodic pattern determines the symmetry and spacing of the diffraction pattern.

In a typical X-ray diffraction experiment, a beam of monochromatic X-rays is collimated onto a crystal. Diffraction by the periodic array of atoms in the crystal leads to a complex pattern of constructive and destructive interference at the detection plane, which can be a photographic plate, fluorescent screen or area detector. In this experiment, we will make a change of scale. By using dots and lines with spacings of about 10^{-4} m (instead of atoms with spacings of about 10^{-10} m) visible light can be used instead of X-rays to create diffraction patterns. You will shine red laser light (670 nm wavelength) through slides containing repeating patterns and observe diffraction. Mathematically, the equations for Fraunhofer and Bragg diffraction have a similar functional dependence** on d, λ and the scattering angle (ϕ or ø), where d is the perpendicular spacing between adjacent rows and λ is the wavelength of the laser light.

** In fact, the Bragg equation can be derived from the equations for Fraunhofer diffraction extended to three dimensions.

Experimental

The laser provided should be handled with caution. It is very low power but can cause eye damage if pointed directly into the eye. Before proceeding read the following:

CAUTION!

IDENTIFY THE END OF THE LASER FROM WHICH LIGHT WILL BE EMITTED *BEFORE* TURNING THE LASER ON.

WHEN USING THE LASER:

- **DO NOT LOOK DIRECTLY AT THE LASER BEAM.**
- **DO NOT POINT THE LASER AT ANYONE.**
- **DO NOT POINT THE LASER AT SHINY OBJECTS, AS IT COULD BE REFLECTED INTO SOMEONE'S EYE.**

Set up the slide holder and laser on a table or stool in a room that can be darkened. Use a whiteboard or piece of paper for the projection of the diffraction pattern. The laser should be at least 2 meters from the screen. *Measure the distance and write it down.*

1. Look at the diffraction patterns produced by the three 1D lattice (grating) slides (1a-1c). What characteristic(s) of the diffraction patterns change(s)? What is the symmetry of the diffraction pattern? Examine these slides under the microscope. What relationship(s) can you observe between the pattern on the slide and the generated diffraction pattern?

2. For each of these 1D lattices (1a-1c), calculate the lattice spacing from the observed diffraction patterns. The angle ϕ is sufficiently small that $\sin \phi$ can be replaced by ϕ (measured in radians). The wavelength of the laser is 670 nanometers. Report your results in millimeters.

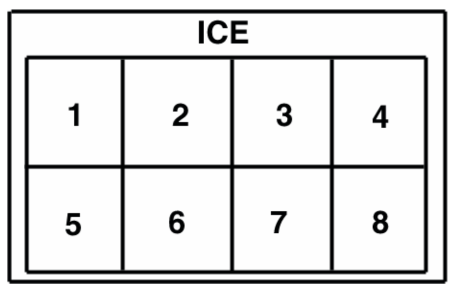
3. Measure the lattice spacings on the same slides using the microscope. How do your calculated results compare to the measured ones?

4. Look at the diffraction pattern from slide 5d. What symmetry do you observe? This lattice has no symmetry except translation. How does this compare to what you observe in the diffraction pattern? (Hint: Remember the simple 1D lattices and the symmetry of their diffraction patterns.)

5. Examine the diffraction pattern of slide 5a. What symmetry do you observe? How does this compare to the reported lattice symmetry, p4?

6. Now look at the diffraction patterns of slides 5b and 5c. What symmetry do you observe in the diffraction patterns and how does this compare to the lattice symmetry? Practice sketching unit cells for these diffraction patterns. Choose coordinates of the diffraction pattern that are consistent with the symmetry. Some diffraction spots are weak, some are strong, and some are absent (not observable). Do you notice any *systematic* absence*s*? If we use h and k (in place of n) to represent the integers describing which order of diffraction you are seeing in the two different directions in your unit cell, describe the absences you see (e.g., $(0, k)$ $k = 2n + 1$).

Now that you are more familiar with the relationships between what is present in the lattice and what is observed in the diffraction pattern , do the following exercise with the slide labeled ICE. This slide has 8 different lattice arrays, which are shown in the following pages. DO NOT USE THE MICROSCOPE FOR THIS EXERCISE. Your goal is to assign the appropriate lattices based only on the diffraction patterns you observe.



For each of the 8 arrays, answer the following questions:

1. Identify the symmetry of the diffraction pattern. What does this imply about the symmetry of the array pattern?

2. Make tracings of the diffraction pattern, remembering to note spot intensities.

3. Choose a coordinate system for the diffraction pattern. Measure the relative distances and angles of this *reciprocal lattice* and estimate the uncertainties.

4. Calculate the lattice spacing for each pattern from the diffraction equation. Report your results in mm. What is the unit cell of the array pattern in mm and degrees?

5. Look carefully for any systematic absences in the diffraction patterns. Describe any absences in terms of h and k, as you did earlier.

6. Based on the answers to the above questions, match the diffraction of the 8 lattices (1-8) with the appropriate patterns (a-h). Remember to discuss WHY you choose the matches that you do. Include dissenting opinions from group members, if any.

Each group should prepare one typewritten report of this exercise.