Optics
Wave Behavior in Optics
Diffraction

Lana Sheridan

De Anza College

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Last time

- Interference of light: the Double-Slit experiment
- multiple slit interference
- diffraction gratings

Overview

- X-ray diffraction
- diffraction patterns

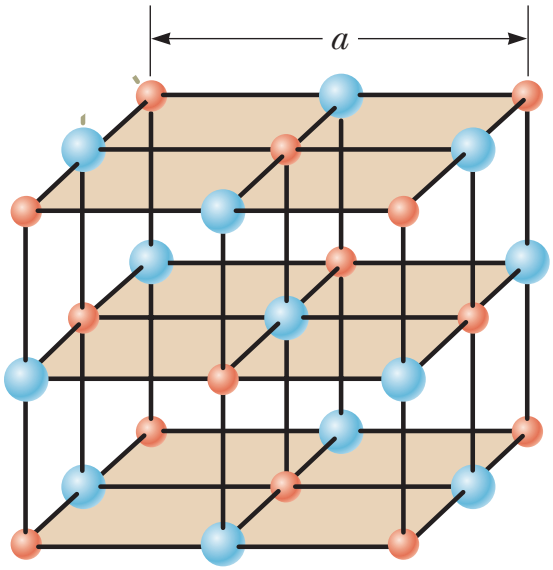
X-ray Diffraction

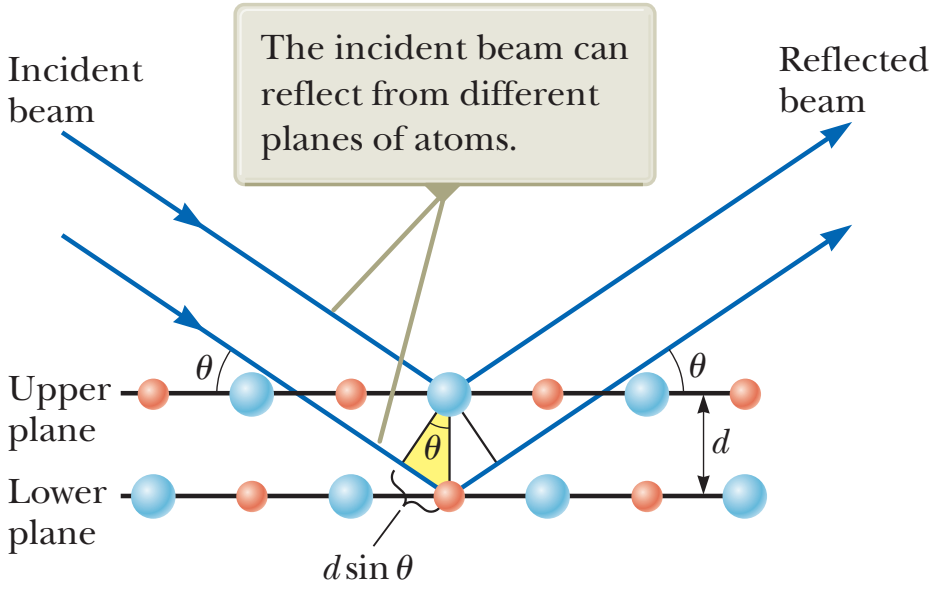
X-rays can be used to study the structure of matter.

The wavelength of X-rays is around 0.1 nm. (0.01–10nm)

This is roughly the interatomic spacing. Layers of atoms can act as a diffraction grating!

X-ray Diffraction



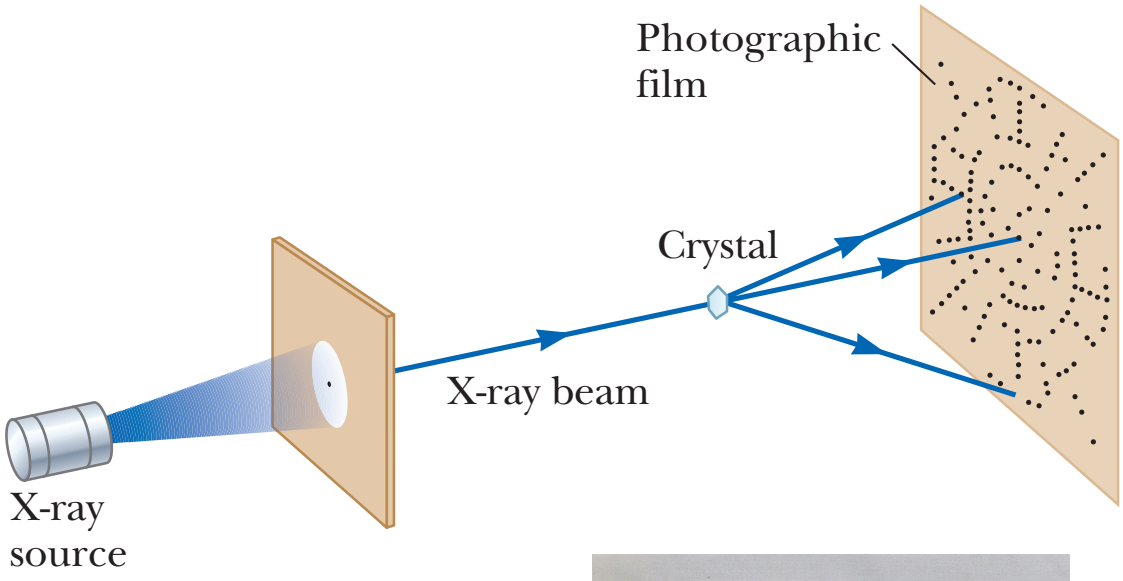


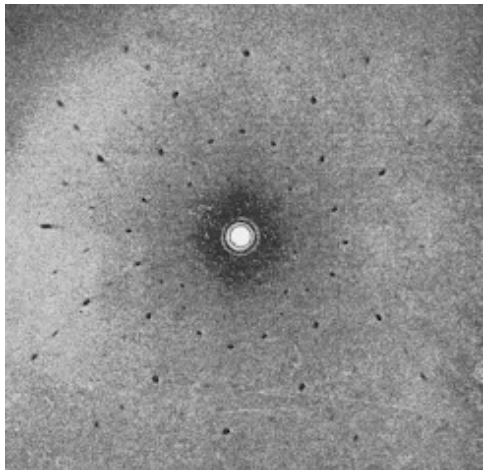
The ray reflecting from the lower layer travels an extra path length of $2d \sin\theta$.

Bragg's Law

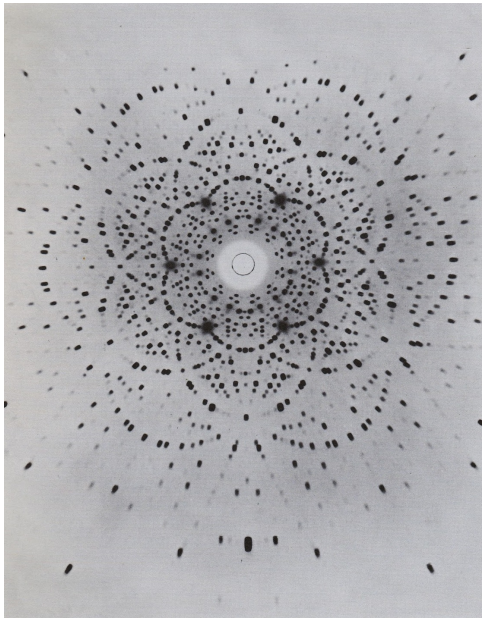
$$2d \sin\theta = m\lambda \qquad m \in \mathbb{Z}^+$$

X-ray Diffraction





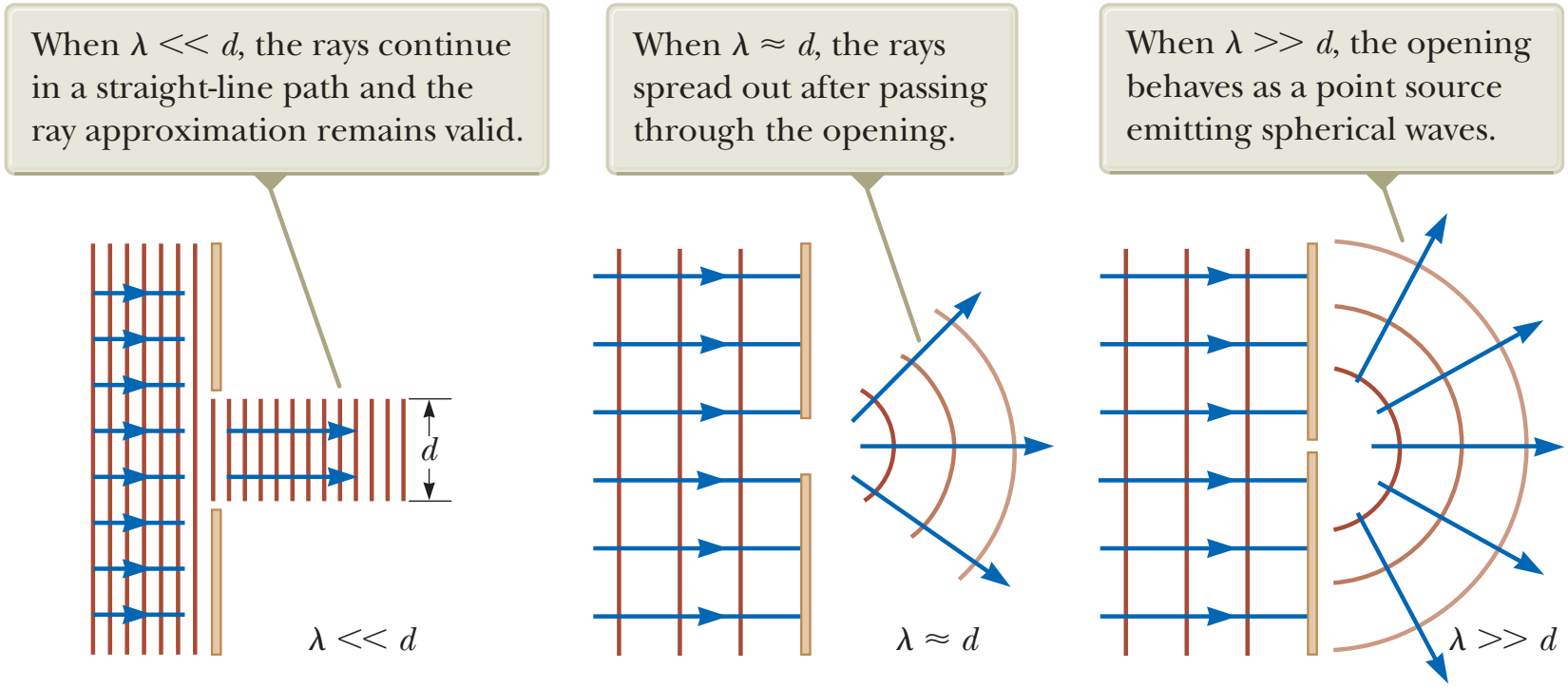
NaCl x-ray crystallograph



from another crystal

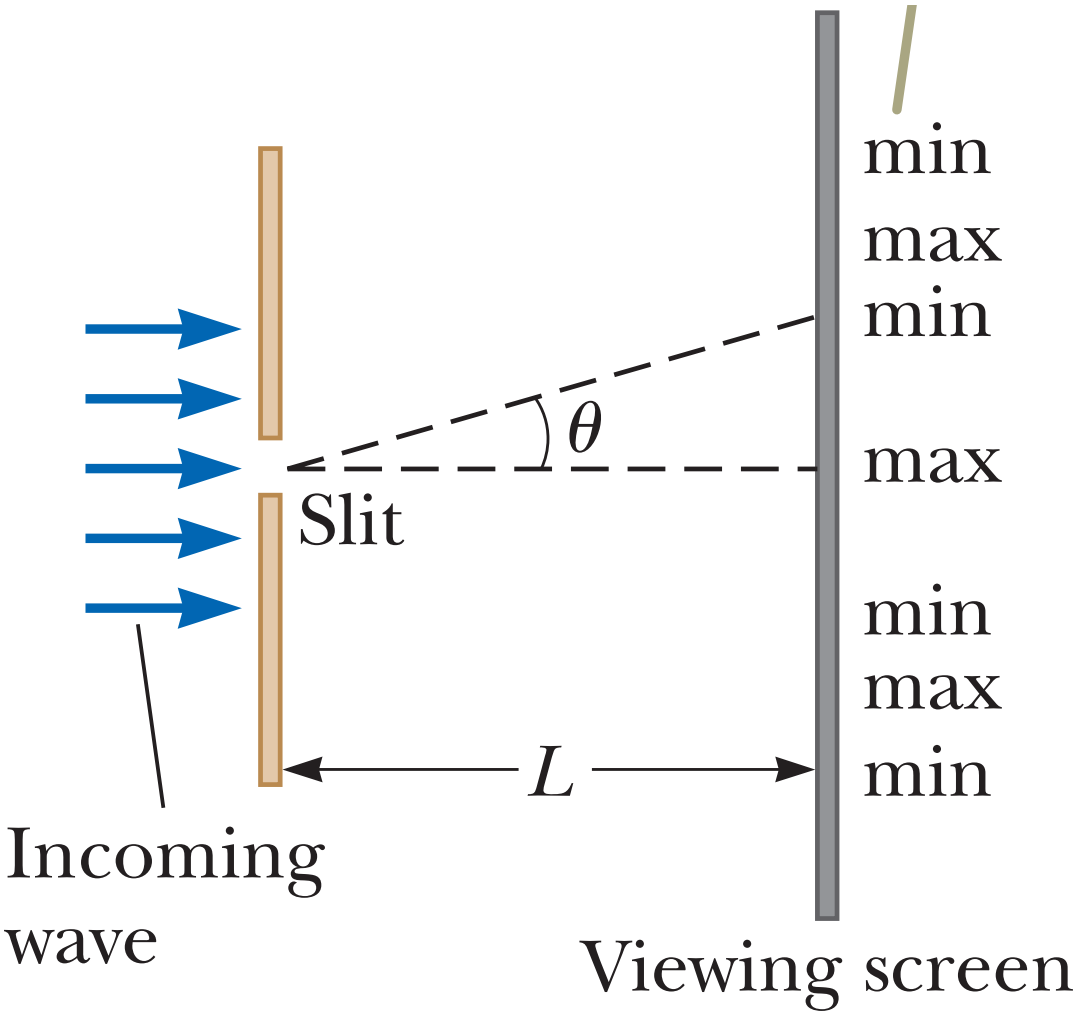
Diffraction

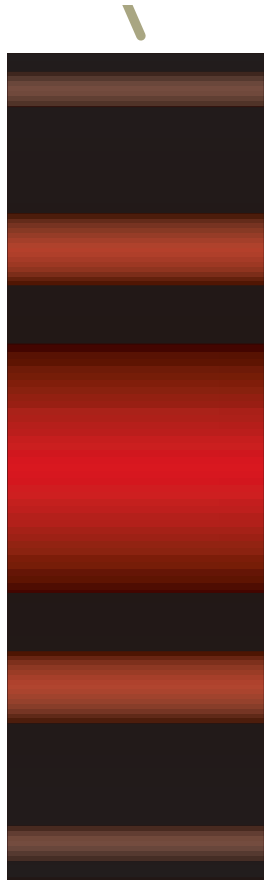
We already know that light and other waves that travel through a small gap ($< \lambda$) diverge, and that the smaller the gap, the more divergence.



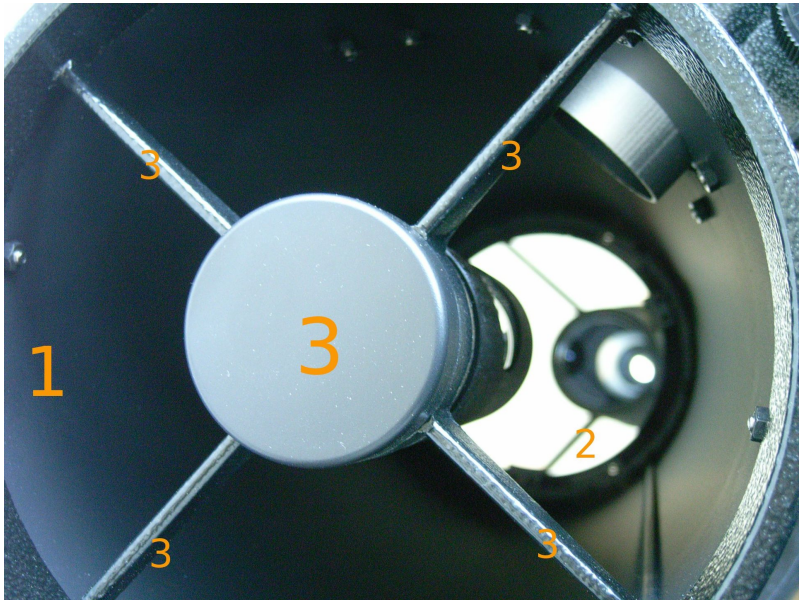
The intensity of light in each direction is not the same however.

Diffraction Patterns





Diffraction Spikes

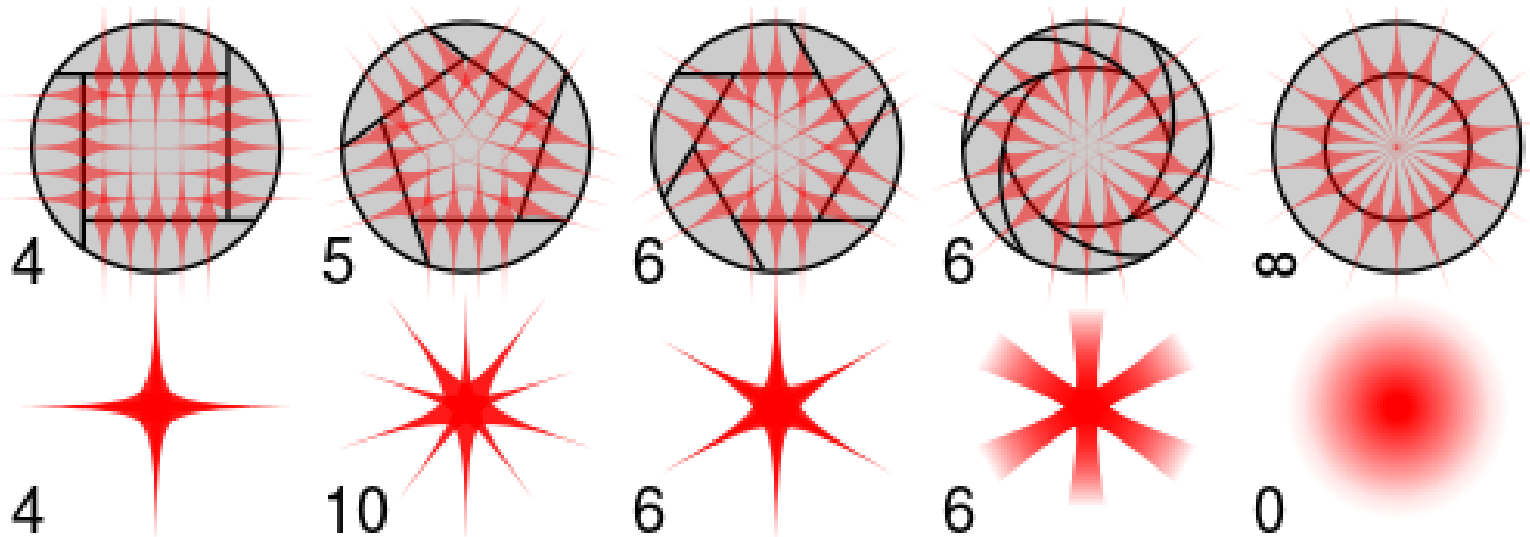


[1]NASA, ESA, and H. Richer (University of British Columbia); Svon Halenbach

Diffraction Spikes in Camera Apertures

Iris diaphragms adjust the amount of light allowed into a camera body.

They cause characteristic diffraction patterns on photos taken of bright lights.

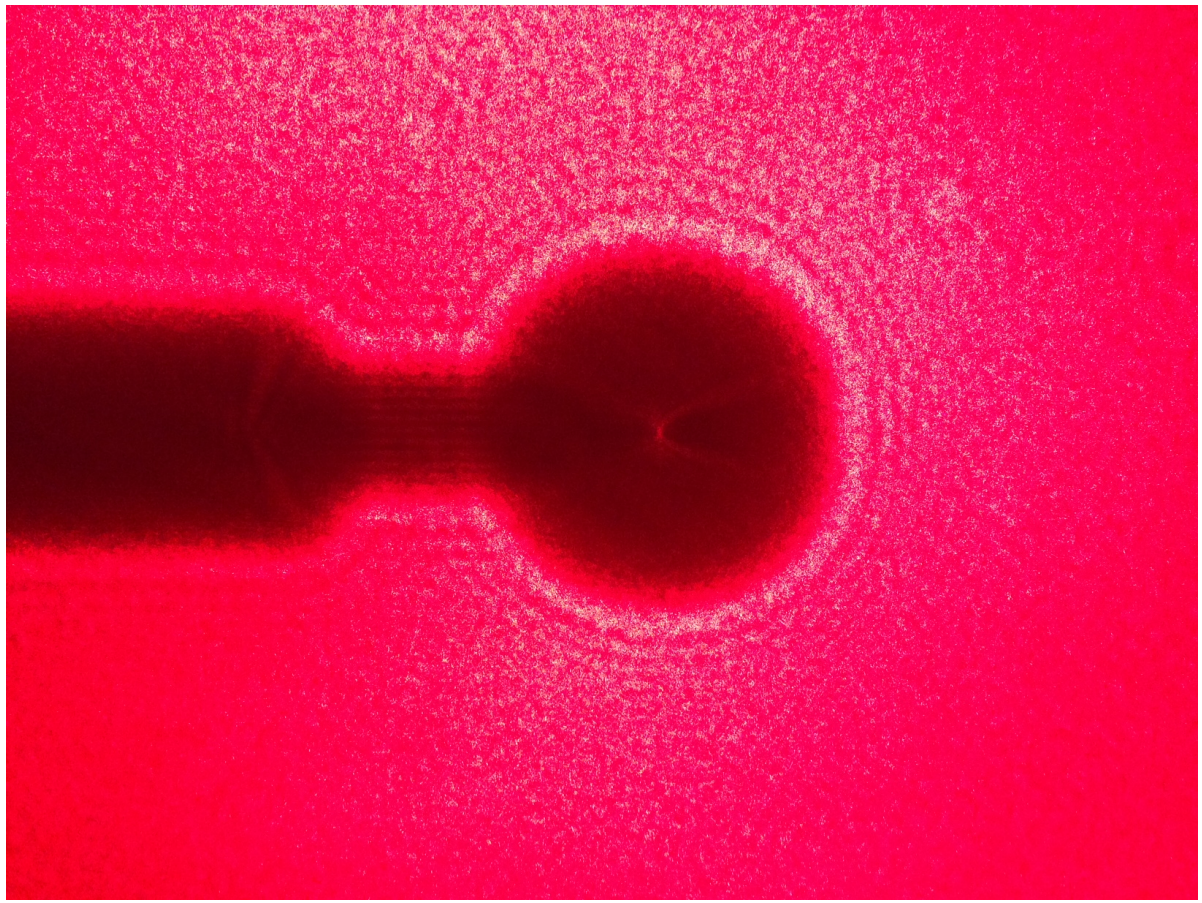


[1]Wikipedia user Cmglee

Diffraction Patterns: Arago Spot

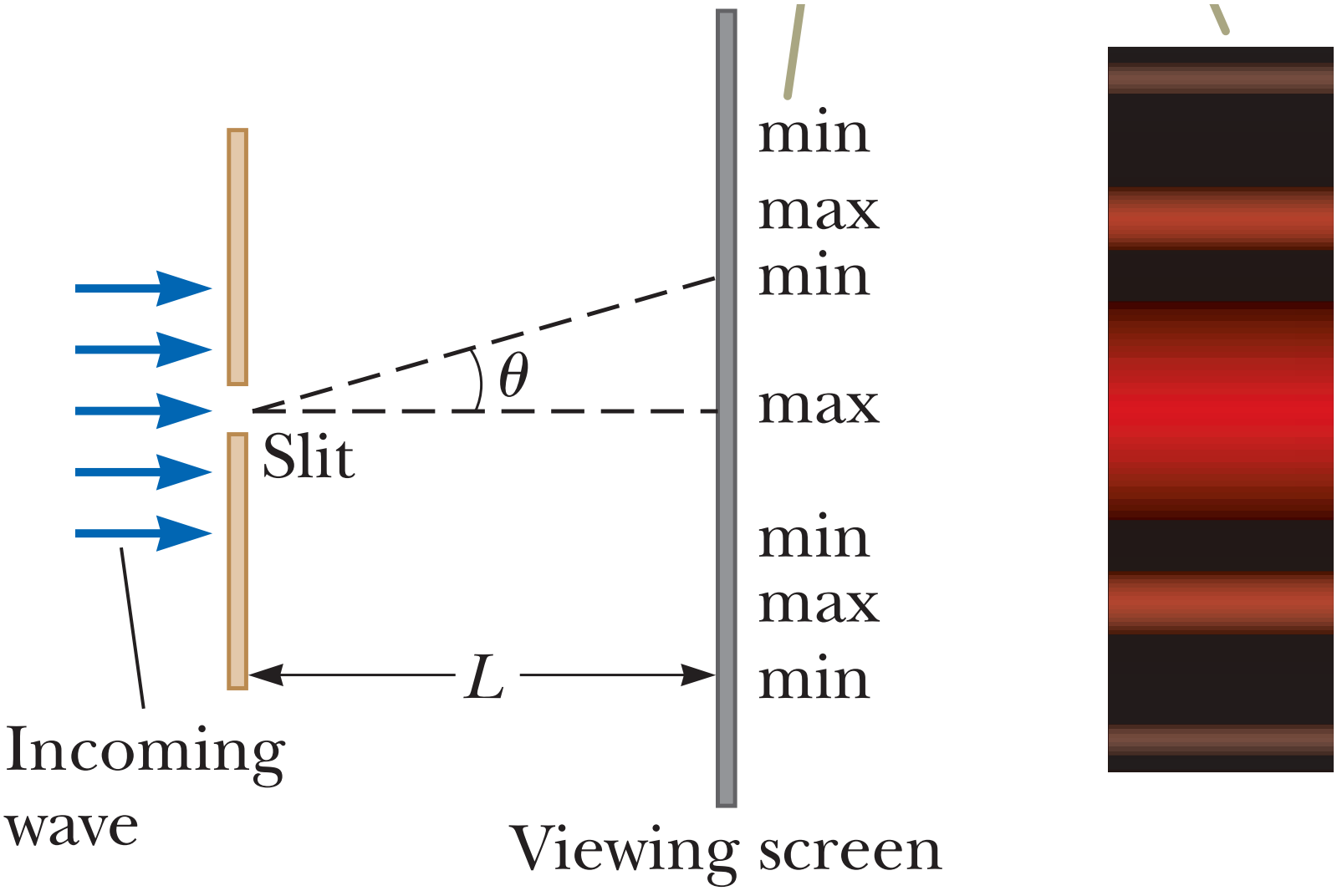
Directly in the center of the shadow produced by a round object lit with coherent light, a spot of light can be observed!

This is called the Arago spot, Fresnel bright spot, or Poisson spot.



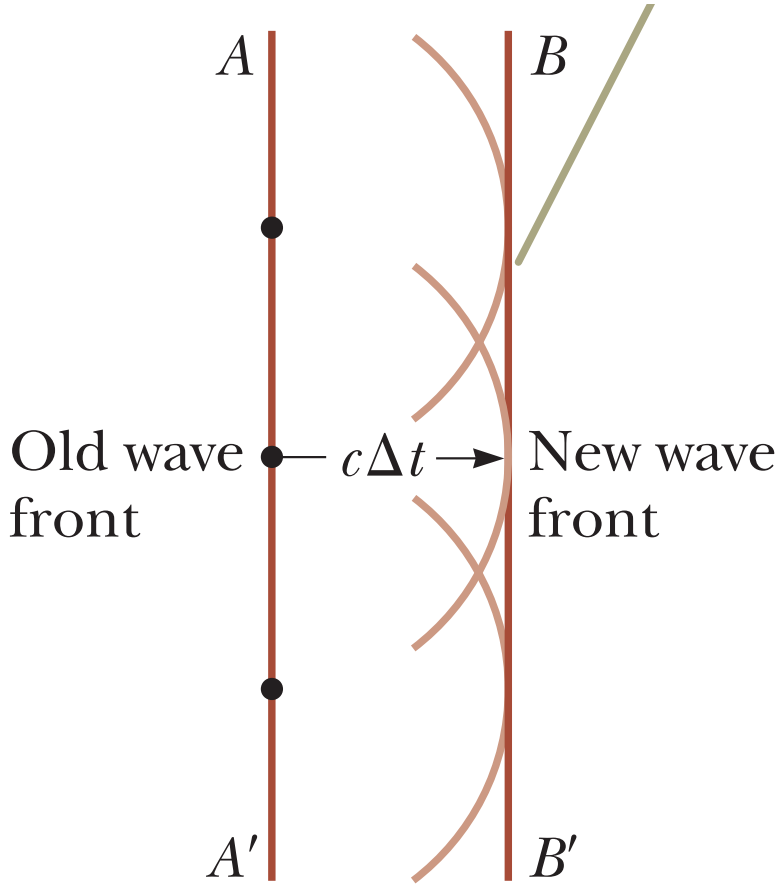
[1] Photo taken at Exploratorium in SF, own work.

Understanding the Diffraction Pattern from a Single Slit



Diffraction and Huygens' Principle

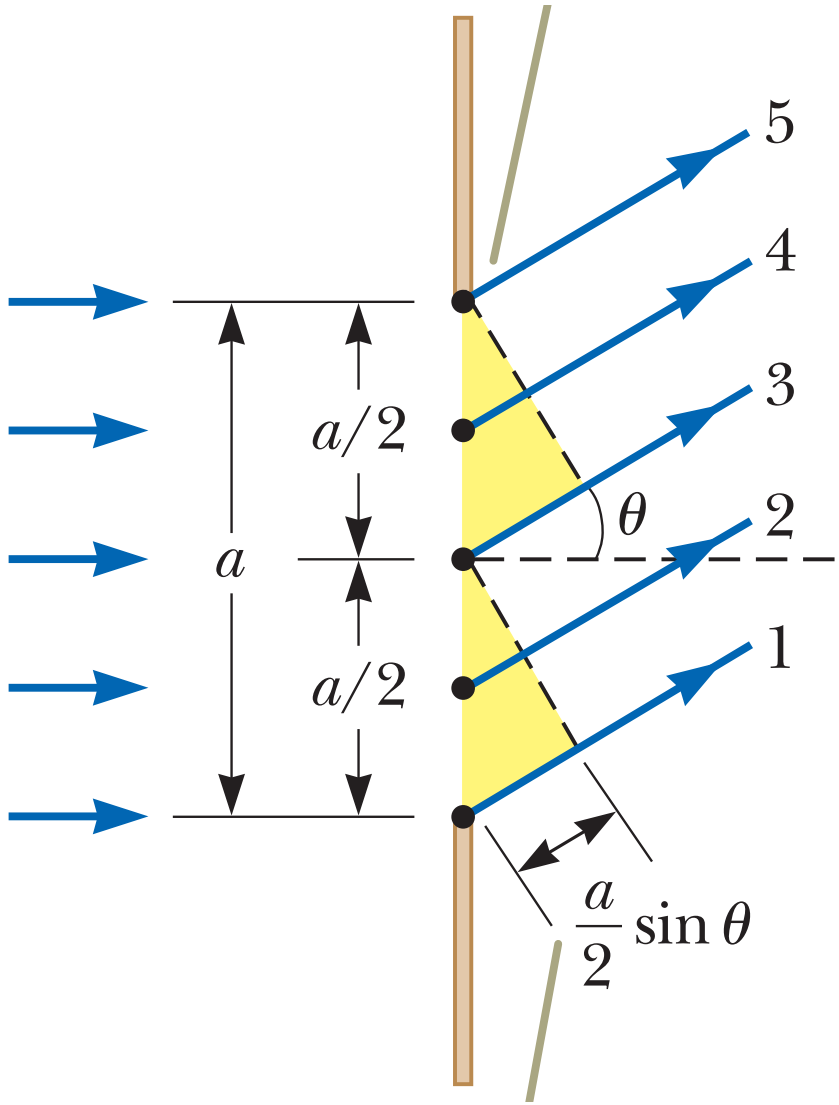
When we have a slit or aperture illuminated by coherent light, each part of the aperture acts as a point source of spherical wavelets.



These wavelets interfere to produce a diffraction pattern.

Understanding the Diffraction Pattern from a Single Slit

Consider a series of point sources in different parts of the slit. The slit has width a.



Understanding the Diffraction Pattern from a Single Slit

We can find minima (dark fringes) in the pattern by breaking up our point sources into pairs that cancel each other out.

Matching point sources in the top half of the slit with ones in the bottom half, the source separation distances will be $d = a/2$.

This will be a fringe dark when:

$$\delta = \frac{a}{2} \sin\theta = \frac{\lambda}{2}$$

Understanding the Diffraction Pattern from a Single Slit

However, we could also break the slit up into 4 equal parts and match sources from the 1st and 2nd, and match from the 3rd and 4th.

This will be dark when:

$$\delta = \frac{a}{4} \sin\theta = \frac{\lambda}{2}$$

If we break the slit up into 6 equal parts and match sources from the 1st and 2nd, the 3rd and 4th, and the 5th and 6th.

This will be dark when:

$$\delta = \frac{a}{6} \sin\theta = \frac{\lambda}{2}$$

Understanding the Diffraction Pattern from a Single Slit

In general we expect dark fringes when:

$$\sin\theta_{\text{min}} = m\frac{\lambda}{a} \qquad \text{where } m = \pm 1, \pm 2, \pm 3, ...$$

Summary

- X-ray diffraction
- diffraction patterns

Collected Homework! due Monday, June 18.

Final Exam 9:15-11:15am, Tuesday, June 26.

Homework Serway & Jewett:

- prev: Ch 38, onward from page 1182. CQs: 5; Probs: 25, 60
- new: Ch 38, OQs: 3, 5; Probs: 1, 7, 10, 41