# Lecture 32

## X-ray diffraction

- X-rays are EM radiation w/ wavelength $\lambda$ of the order 1 Å ($= 10^{-10}$ m)
- Smaller than wavelength of visible spectrum centered @ 550 nm

- A standard optical grating cannot be used to discriminate between different wavelengths in x-ray regime.

- For $\lambda = 1$ Å $= .1$ nm &
  $d = 3000$ nm

(2)

1st order maximum occurs @

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

$$= \sin^{-1}\left(\frac{(1)(0.1\,nm)}{3000\,nm}\right) = 0.0019^\circ$$

too close to central maximum to be practical.

- Desirable to have $d \approx \lambda$, but this is not possible mechanically for x-rays.

- In 1912, von Laue realized that a crystalline solid consisting of a regular array of atoms could be useful as a 3D diffraction grating.

(show slides)

How does this work?

- When an x-ray beam enters a crystal, the x-rays are scattered (redirected in all directions) by the crystal structure.

- In some directions, scattered waves undergo destructive interference, giving intensity minima

- In other directions, constructive interference, giving inten

How to determine directions?

"Fictional planes"

- process is complicated, but it turns out that maxima ~~turn out to be in~~ are directions as if x-rays were reflected by a family of parallel reflecting planes

(show slides)

figure shows 3 planes w/ interspacing $d$.

- Angle $\theta$ is formed wrt surface (different from usual)

(show slides)

- determine interference by path length differences

- path length difference of adjacent rays is $2d \sin\theta$
- for them to be in phase path length difference should be an integer # of wavelengths:

$$2d \sin\theta = m\lambda \quad \text{for } m = 1, 2, 3, \ldots$$

(called Bragg's law)

- If rays enter @ a different angle, there could be a different family of planes used for analysis that are related to reflection

# photons & matter waves Ch. 38

Quantum physics is the
- study of the microscopic world

- word "quantum" comes about

  b/c basic objects are
  "quantized" coming in
  discrete amounts.

- For example U.S. currency
  is quantized w/ fundamental
  unit being the penny.

- In 1905, Einstein proposed that
  light is quantized & the
  elementary unit is the <u>photon</u>.

- quantum of a light wave of frequency $f$ has energy

$$E = hf$$

where $h = 6.63 \times 10^{-34}\ J \cdot s$ is the Planck constant

- If the wave has more energy, it is an integer multiple of $hf$.

- photons are absorbed & emitted by atoms, as proposed by Einstein.