Davisson-Germer experiment

Davisson and Germer experiment involves scattering of electrons by single crystal Nickel (Ni). The experimental set up is schematically represented in fig(1) below.

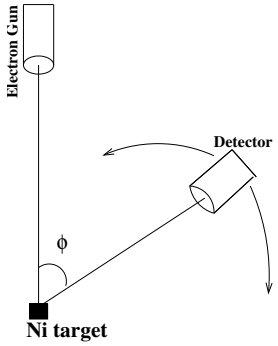

Figure 1:

A single crystal Ni target is bombarded with electron beam from an electron gun. The electrons scattered from the target is received at a detector which can be moved along the circular path around the target. By moving around, the detector captures electrons that are scattered at different angles with respect to the incident radiation. If the electrons really do display a wave like behaviour, one should expect the kind of variation of intensity when one shines this target with a electromagnetic wave of the same wavelength, namely X-rays. This variation of intensity is the diffraction pattern of X-rays. By measuring the number of electrons scattered at different angles with respect to the incident beam one can find out whether it has a pattern similar to that of X-ray diffraction.

Davisson-Germer experiment done with electron beam at different energies displays a variation in the number of electrons with the angle of scattering measured from the incident beam as shown in fig(2). In the plot below the Y-axis is chosen to lie along the direction of incident beam. The number of electrons scattered at a particular angle ϕ is specified by a point on the line at that angle from the incident beam in such a way that the distance of the point from the origin is proportional the number of electrons. At a particular energy 54eV of the electron beam, we can see that the intensity of the scattered electrons is the highest in a direction that is at $\phi = 50°$ from the line of incident beam.

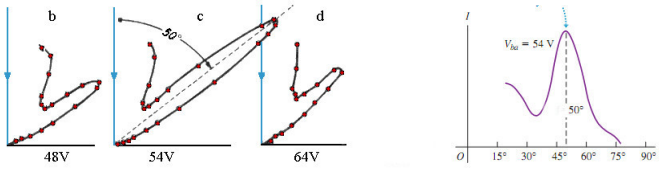

Figure 2: On the left, intensity is represented by distance of points on the curve from origin. On the right, same data plotted in the familiar method (Source : leifiphysik.de, physicaalert.weebly.com)

The diffraction patterns of X-rays can be explained by using the schematic diagram in the fig(3) below. We let parallel beams from a distant source of X-ray fall on the crystal. The

distance travelled by beams that get reflected away from different Bragg planes are different, leading to a phase difference between the beams in general. The beams will have no phase difference only if the difference in distance travelled by the two beams are an integral multiple of the wavelength λ. If we consider two beams that get reflected from the consecutive Bragg planes of the crystal shown in fig(3), the extra distance travelled by the beam from the lower plane is $CB + BD$. In terms of the distance d between the Bragg planes and the angle θ indicated in fig(3), the path difference between the beams is $CB + BD = 2d\sin(\theta)$. For two such beams to interfere constructively, we must have

$$2d\sin\theta = n\lambda \tag{1}$$

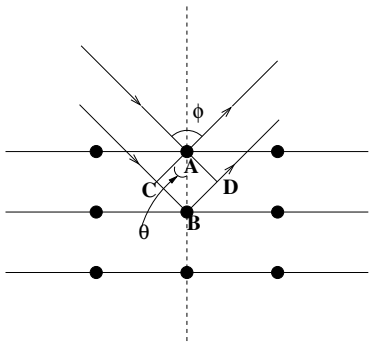

Figure 3:

Single crystal Ni has a distance of 0.091nm between its Bragg planes. As stated earlier, for the electron beam with kinetic energy 54eV we find that the first peak at $\phi = 50°$. This gives $\theta = 90 - \frac{\phi}{2} = 65°$. Thus, with $n = 1$ we find that the wavelength of the electron has to be

$$\lambda = 2 \times 0.091 \times 10^{-9} \times \sin 65° = 0.165\text{nm}$$

If de Broglie's hypothesis is correct it must provide us the same value of wavelength. The de Broglie wavelength for an electron with $KE = 54$eV is

$$\lambda_{\text{de Broglie}} = \frac{h}{p} = \frac{h}{\sqrt{2m(KE)}} \frac{6.626 \times 10^{-34}}{2 \times 9.1 \times 10^{-31} \times 54 \times 1.6 \times 10^{-19}} = 0.165\text{nm}$$

This agreement strongly supports the de Broglie's hypothesis. Still one needs to understand what types of waves are de Broglie waves.