

## MODERN PHYSICS EXPERIMENT

### ELECTRON DIFFRACTION

#### Reference

Tipler, 3rd Edition, Section 35-6.  
F.J. Blatt, Modern Physics, Chapter Six.

#### Introduction

In 1924 the French physicist Louis de Broglie suggested that, whenever there are particles of momentum  $p$ , their motion is associated with a wave of wavelength  $\lambda$ , given by the following expression:

$$\lambda = \frac{h}{p} \quad (1)$$

where  $h$  is Planck's constant.

The first experimental evidence of the existence of matter waves was found by C. Davisson and L.H. Germer at the Bell Telephone Laboratories in 1927.

They 'reflected' slow electrons from a single crystal of nickel and applied the de Broglie's relationship  $\lambda = h/p$ , and so determined the wavelength.

At the same time the wavelength of the electrons was determined from the Bragg's expression. Excellent agreement was found.

In this experiment it is possible to make interference (a wave property) in the electron beam visible. Quantitative evaluation of the diffraction pattern (caused by interference) yields experimental confirmation of the de Broglie relationship, demonstrating the wave nature of matter (electrons in this case).

#### Apparatus

1. Electron diffraction tube.
2. Power supply 0-5 kV.
3. 6 V A.C. transformer.
4. Ammeter 0-0.5 A.

## Description of the Diffraction Tube

The operating elements of the tube:- an indirectly heated cathode, the anode and a graphite foil (used as diffraction element) are housed in an evacuated glass bulb.

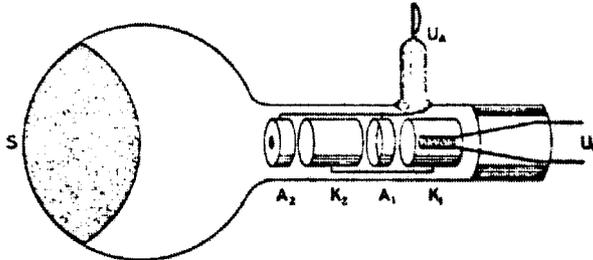


Fig.1

As shown in Fig. 1 the system of electrodes consists of 4 metal cylinders arranged one after the other. The electrodes are connected in pairs, cathode potential K1, K2 and anode high potential A1, A2. A1, K2, A2 act as an (electrostatically) focussing lens. The indirectly heated cathode acts as an electron source.

Anode A2 is a thin polycrystalline graphite foil used as a diffraction element. The focussed electron beam strikes the graphite foil at an angle of  $90^\circ$ .

Some electrons after passing the graphite foil are diffracted and reach the fluorescent layers and give luminous (green) rings.

The intense luminous spot produced in the middle of the screen is due to the direct (non-diffracted) electron beam. It is sometimes useful to cover this spot, since it is very bright, to make the diffracted rings more readily visible.

## Theory

The electrons 'reflected' from lattice atoms will produce interference patterns according to Bragg's rule.

$$2d \sin\theta = n\lambda \quad (2)$$

where

$n$  = order of reflection

$d$  = interplanar spacing of the three dimensional lattice

$\theta$  = reflecting angle

$\lambda$  = wavelength of the electrons.

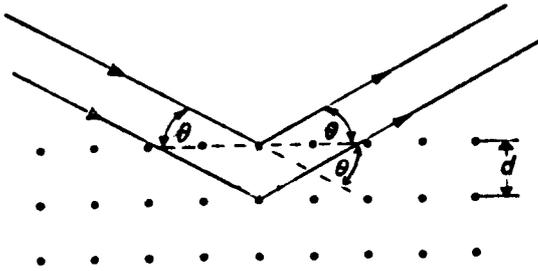


Fig. 2

The observed diffraction pattern consists of rings of various radii produced by the constructive interference of the electron wave diffracted from the various families of planes within the randomly oriented crystals in the thin film target (graphite in this case).  $\theta$  is the angle between the incident beam and the reflecting plane, which is the same as the angle between the reflected beam and the reflecting plane. Therefore, between the direct and diffracted beam is  $2\theta$ .

Polycrystalline graphite foil

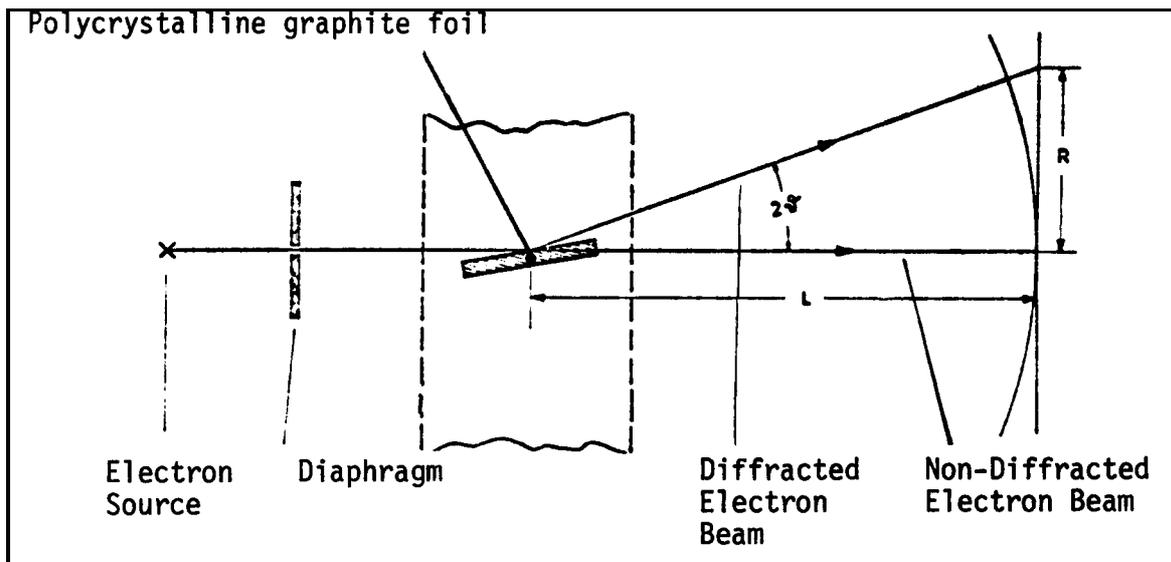


Fig. 3

From Fig. 3 -

$$\tan 2q = \frac{R}{L}$$

for small value of angle  $\theta$

$$\tan 2q \approx \sin 2q \approx 2 \sin q$$

$$2 \sin q = \frac{R}{L}$$

substituting from equation 2 -

$$\frac{n\lambda}{d} = \frac{R}{L}$$

$$\lambda = \frac{d}{L} R \quad \text{for the case } n = 1$$

If  $d$ ,  $L$  and  $R$  are known,  $\lambda$  can be calculated. The value of  $L$  is fixed for a particular apparatus.  $R$  can be measure. If  $d$  is known,  $\lambda$  can be calculated, or if  $\lambda$  is known,  $d$  can be calculated.

In this experiment, the value of  $d$  for graphite is given and you are expected to calculate  $\lambda$ .

This value of  $\lambda$  can be verified with the help of de Broglie's equation

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

The kinetic energy of the electrons will be

$$\frac{1}{2} mv^2 = eV,$$

where  $V$  is the numerical value of the accelerating voltage in Volts and  $e$  is the charge of the electron in coulombs.

$$\begin{aligned} \lambda &= \frac{h}{\sqrt{2e mV}} \\ &= \sqrt{\frac{150}{V}} \times 10^{-10} \text{ m} \end{aligned}$$

### Experimental Procedure

**WARNING!** Be careful in connecting the high voltage wire to the diffraction tube apparatus. If for any reason the diffraction tube is to be removed, call your instructor. The tube is evacuated to a pressure of  $10^{-8}$  mm Hg and should be handled with caution to avoid implosion.

1. Connect the circuit as shown in Fig. 4.



4	3200										
5	3600										
6	4000										

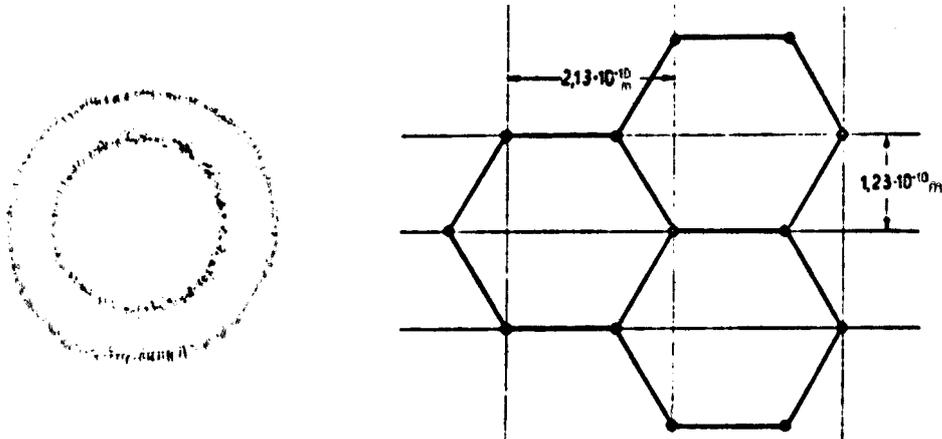


Fig. 5

**Note**

If a satisfactory diffraction pattern is not produced then use the adjusting magnet around the neck of the tube (Fig. 6.) Rotate or shift the magnet till you see at least two diffracted rings.

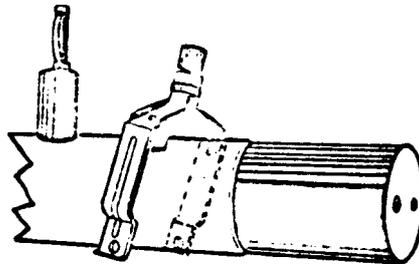


Fig. 6

**Problems and Questions**

1. Discuss in brief an experiment which could be performed with the electron diffraction tube to demonstrate that the diffraction pattern is due to electrons and not due to electromagnetic radiation.
2. Explain why the ring diameters increase with decrease in voltage.
3. Prove that  $I(A) = \sqrt{\frac{150}{V}}$ .

4. Would the above equation be valid for 10 MeV electrons? If not, why not? Derive an equation which would apply.
5. Assume that the electron beam is replaced with a beam of positively charged particles. Could you do the same experiment? What would be the result if the particles were protons?
6. Plot a graph  $\lambda^2$  vs  $1/V$  where  $\lambda$  is in angstroms and  $V$  in Volts. Use the data obtained from de Broglie's relationship. What is the significance of the slope?
7. Why does the diffraction pattern consist of circles? Explain why only two concentric circles are formed. Would a single crystal produce the same pattern? Explain.

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