ELECTRON DIFFRACTION

OBJECTIVE

Observe the diffraction of electrons on polycrystalline graphite and confirm the wave nature of electrons.

EXPERIMENT PROCEDURE

- **Measuring the diameters of the two diffraction rings for different accelerator voltages.**
- **Determining the wavelength of the electrons for different accelerator voltages by applying the Bragg condition.**
- **Confirming the de Broglie equation for the wavelength.**

SUMMARY

The diffraction of electrons on a polycrystalline graphite foil provides evidence for the wave nature of electrons. It is possible to observe two diffraction rings surrounding a central spot on the axis of the beam on the fluorescent screen of the electron diffraction tube. These rings are caused by the diffraction of electrons at those lattice planes of the microcrystals in the graphite foil that satisfy the Bragg condition. The phenomenon is similar to the results obtained in the Debye-Scherrer diffraction of X-rays by a crystalline powder.

REQUIRED APPARATUS

Quantity	Product	Number
1	Electron Diffraction Tube S	**1013889**
1	Tube Holder S	**1014525**
1	High Voltage Power Supply 5 kV (230 V, 50/60 Hz)	**1003310 or**
	High Voltage Power Supply 5 kV (115 V, 50/60 Hz)	**1003309**
1	Set of 15 Safety Experiment Leads, 75 cm	**1002843**

BASIC PRINCIPLES

In 1924 *Louis de Broglie* put forward the hypothesis that particles can in principle also possess wave properties, and that the wavelength depends on the momentum. His theories were later confirmed by *C. Davisson* and *L. Germer* by observing the diffraction of electrons by crystalline nickel.

According to de Broglie, the relation between the wavelength λ of a particle and its momentum p is given by:

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

h: Planck's constant.

For electrons that have been accelerated by a voltage U_A, this leads to the equation

(2) $$\lambda = \frac{h}{\sqrt{2 \cdot m \cdot e \cdot U_A}}$$

m: Mass of the electron, e: Elementary electric charge.

For example, if the accelerator voltage is 4 kV, one can assign to the electrons a wavelength of about 20 pm.

In the experiment, the wave nature of electrons in an evacuated glass tube is demonstrated by observing their diffraction by polycrystalline graphite. On the fluorescent screen of the tube one observes diffraction rings around a central spot on the axis of the beam. The diameter of the rings depends on the accelerator voltage. They are caused by diffraction of electrons at those lattice planes of the microcrystals that satisfy the Bragg condition:

(3) $$2 \cdot d \cdot \sin \vartheta = n \cdot \lambda$$

ϑ: the Bragg angle, n: Diffraction order,
d: Distance between the lattice planes

(see Fig. 2). The diameter of the diffraction ring corresponding to the Bragg angle ϑ is given by:

(4) $$D = 2 \cdot L \cdot \tan 2\vartheta$$

L: Distance between the graphite foil and the fluorescent screen.

As graphite has a crystal structure with two different lattice plane distances, d_1 = 123 pm and d_2 = 213 pm (see Fig. 3), the first-order diffraction pattern (n = 1) consists of two diffraction rings with diameters D_1 and D_2.

EVALUATION

From the diameters of the two diffraction rings and the distances between the lattice planes, we can determine the wavelength λ by applying the Bragg condition. For small diffraction angles the following equation is valid:

$$\lambda = 2 \cdot d_{1/2} \cdot \sin\left(\frac{1}{2} \cdot \arctan\left(\frac{D_{1/2}}{2 \cdot L}\right)\right)$$

The experimental wavelengths thus calculated can be compared with the values calculated from the theoretical expression (2).

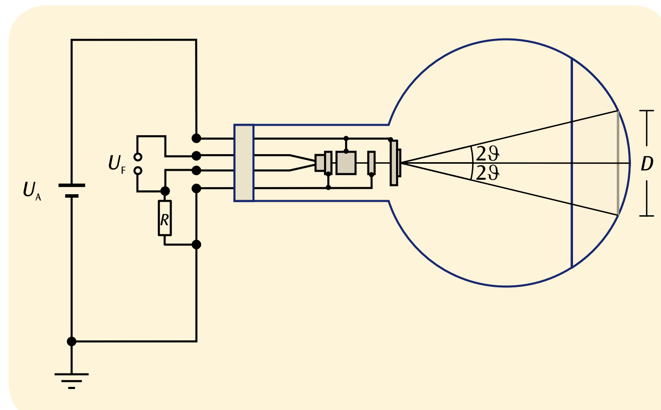

Fig. 1: Schematic diagram of the electron diffraction tube.

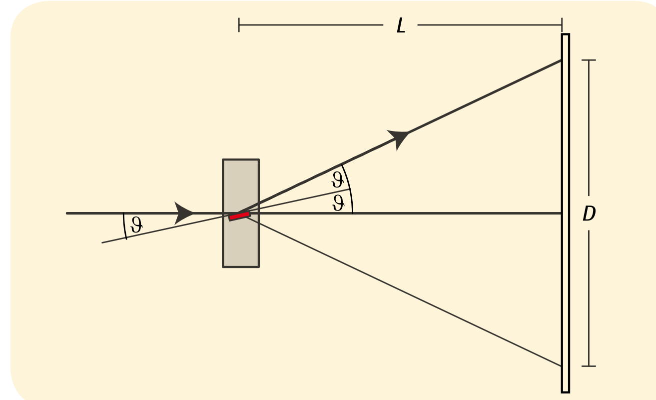

Fig. 2: Bragg reflection at a "favourable" group of lattice planes in a typical crystallite of the graphite foil.

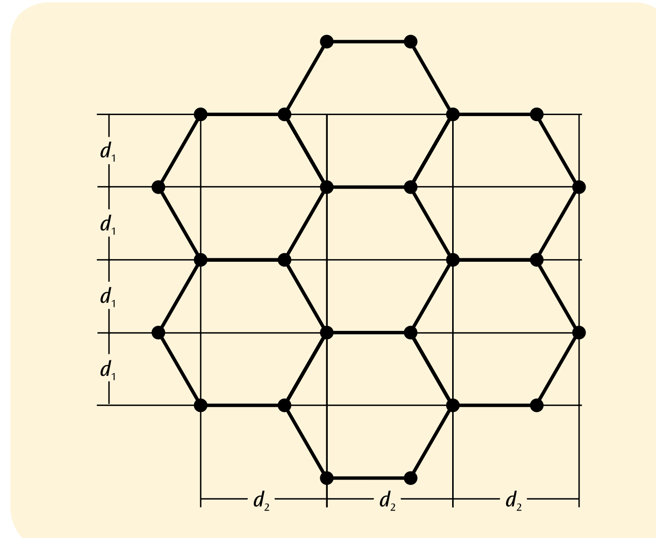

Fig. 3: The crystal structure of graphite.

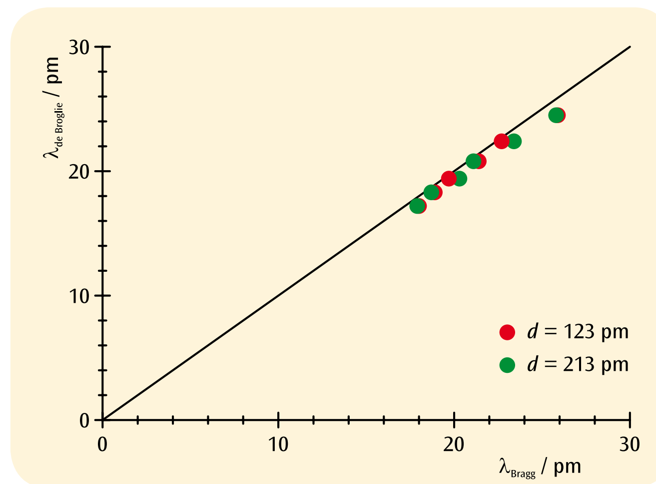

Fig. 4: The relation between wavelengths determined experimentally using the Bragg condition and the theoretical de Broglie wavelengths.