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EXPERIMENT 4: ELECTRON DIFFRACTION

Objective

- Verify the wave-like properties of electrons through diffraction by a thin graphitized carbon foil.
- Utilize a circuit setup with variable DC supplies to accelerate electrons across a potential difference.
- Measure diameters of diffraction rings formed on a phosphor screen to analyze diffraction patterns.
- Assess if observed diffraction patterns support de Broglie's hypothesis of matter-wave duality.

Theory

Wave-Particle Duality: Matter, including electrons, behaves like both waves and particles. De Broglie's equation ($\lambda = h / p$) links the wavelength (λ) of matter waves to the momentum (p) of the particle. De Broglie wavelength for electrons is given by $\lambda = h / 2MeV$ [lambda: wavelength, h being the planck constant Me beign the mass of electron and V being the voltage. Low-energy electrons, typically with energies of a few keV or less, exhibit de Broglie wavelengths comparable to the spacing of atoms in a crystal.

Apparatus Used

➔ 6.3VAC filament supply
➔ Screen to view the electron diffraction for a laser light [green in colour]
➔ Carbon target

➔ Accelerating potential difference to increase the potential difference which eventually deacreases the diameter of the electron diffracting ring diameter

➔ Bias [already set to 0 – 50v]

➔ Variable potential meter

Experiment summary

In contrast,

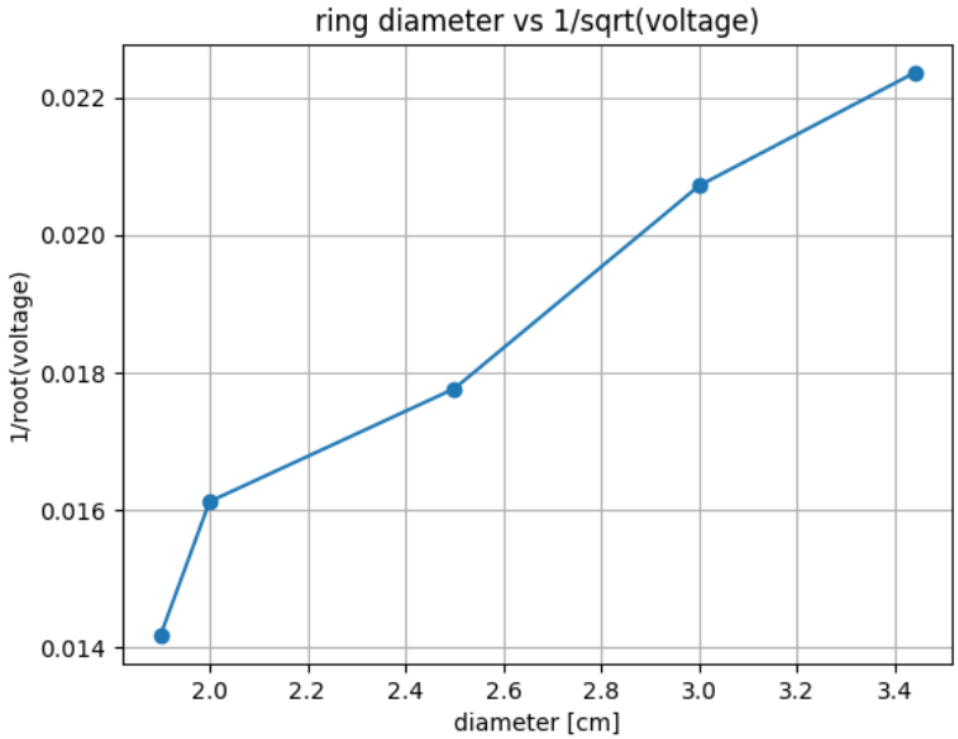
- **➔ I must Switch on the high voltage and allow it to warm for several minutes, keeping the voltage constant [due to voltrage in the accelerating potential difference meter constantly increasing and deacreasing]. By the time, I must familiarize with the appartues being given by the lab assistant professors.**
- **➔ While we were instructed to increase the bias to 20V, our new apparatus didn't need that so we focused on our usual bias voltage value 0V [and the sharpest ring was already adjusted by the lab assistant professors]**
- **➔ By the given magnet which was placed right beside the accelerating potential difference meter, I must 1.1) Observe the phosphor screen of the diffraction tube for a pair of diffraction rings and a brighter central spot and 1.2) confirm that the diffraction rings are produced by moving charged particles**
- **➔ Measure the diameters of the two rings using a ruler, estimating measuring uncertainties. Make at least 5 estimates in various orientations to get an average, and calculate the standard deviation for each average ring diameter.**
- **➔ Record the accelerating potential difference, bias potential, and current.**
- **➔ Repeat the procedure for five more accelerating potentials, increasing up to a maximum of 5000 V. Monitor the anode current to ensure it does not exceed 0.2 mA.**

Analysis

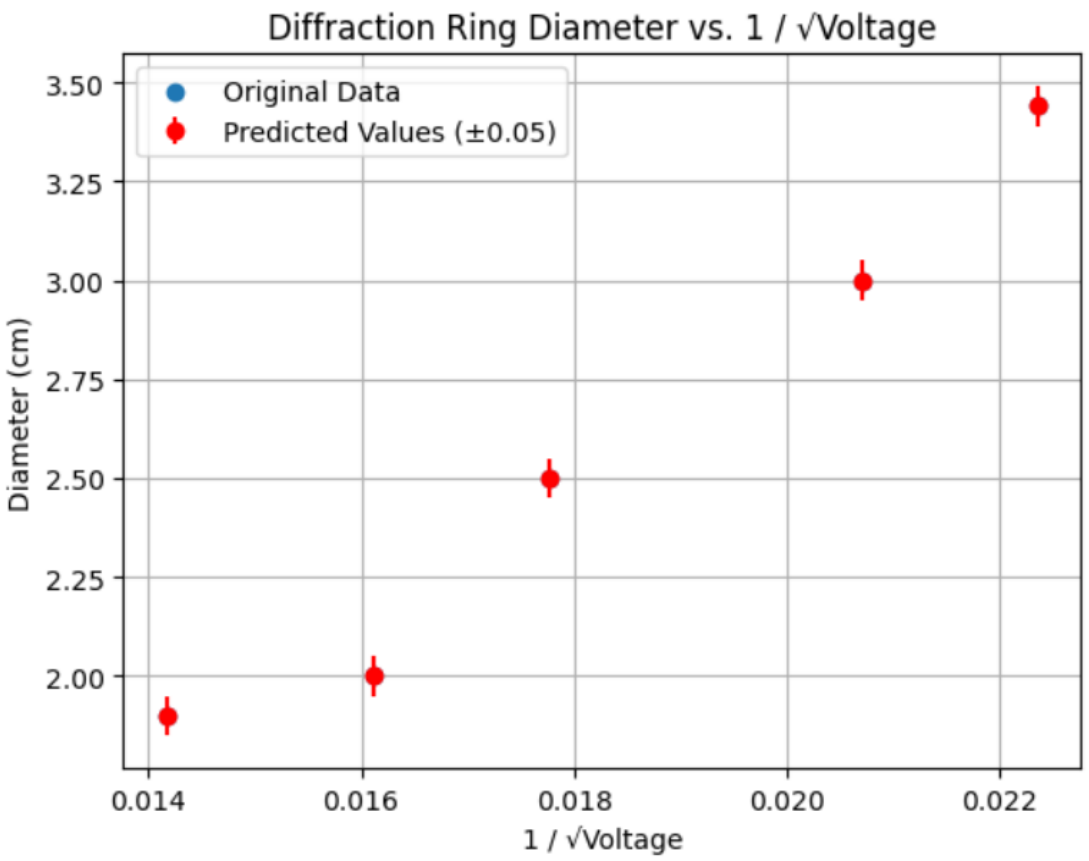
electron diffraction - lab 4 experiment				
voltage	diameter cm	inner diffraction d10 cm	outer diffraction d11 cm	[1/(voltage)]^1/2
2000	3.44	1.893	3.44	0.02236068
2330	3	1.7	3	0.02071677
3170	2.5	1.2	2.35	0.017761121
3850	2	0.985	2.05	0.016116459
4980	1.9	0.9775	1.925	0.014170505
average diffraction		1.9625	2.553	
standard deviation diffraciton		0.377312655	0.578822944	
		1.96 +- 0.377	2.553 +- 0.579	
	L = diffracting ri	0.593 +- 0.202		
d10 value	1.8cm	n = 1 diffraction positon		
d11 value	2.3cm	n = 2 diffraction position		

[the graph and the program denoted below are the set no uncertainty values, the expressed values]

```
import numpy as np
import matplotlib.pyplot as plt

diameter = np.array([3.44, 3, 2.5, 2, 1.9])
inner_outer_diffractions = np.array([0.02236068, 0.02071677, 0.017761121, 0.016116459, 0.014170505])
plt.plot(diameter, inner_outer_diffractions, marker='o', linestyle="-")

plt.title("ring diameter vs 1/sqrt(voltage)")
plt.xlabel("diameter [cm]")
plt.ylabel("1/root(voltage)")
plt.grid(True)
plt.show()
```




```python
import numpy as np
import matplotlib.pyplot as plt

voltages = np.array([2000, 2330, 3170, 3850, 4980])
inverse_sqrt_voltages = 1 / np.sqrt(voltages)
diameters = [3.44, 3, 2.5, 2, 1.9]

predicted_upper = inverse_sqrt_voltages + 0.05
predicted_lower = inverse_sqrt_voltages - 0.05

plt.scatter(inverse_sqrt_voltages, diameters, label='Original Data')

plt.errorbar(inverse_sqrt_voltages, diameters, yerr=0.05, fmt='o', label='Predicted Values (±0.05)', color='red')

plt.xlabel('1 / √Voltage')
plt.ylabel('Diameter (cm)')
plt.title('Diffraction Ring Diameter vs. 1 / √Voltage')
plt.legend()
plt.grid(True)

plt.show()
```



THESE ARE THE UNCERTAINITY VALUES WITH 5 trials for the first 2 while 3 trials for the remaining.

- ➔ **The derived expression for the de Broglie wavelength (λ) indicates that it is inversely proportional to the square root of the applied high voltage (V). If the experimental graphs exhibit this relationship, with smaller diffraction ring diameters corresponding to higher voltages, then it supports de Broglie's hypothesis, which states that the wavelength of a particle decreases as its momentum (or, in this case, kinetic energy) increases**
- ➔ **No, the comparison in between the experimental value and the predicted value for d10 and d11 diffraction grating did match with the predicted**

value for d10 n = 1 set at 1.8cm which the experiment value after 5 trials [1.8, 2.0, 1.81, 1.9, 2.0 respectively] output 1.893cm. For d11 the diffraction position n = 2 was set at 2.3cm while experimentally after 5 traisl [3.5, 3, 3.2, 2.9, 3.4 respectively] was set at 3.2 cm. Reason for this inaccuracy can be due to the measurement especially when measuring the n = 2 diffracting ring diameter led to an inaccuracy of average [2.87 +- 0.5 cm]

➔ **Carbon atoms are arranged in hexagonal layers above one another in the layered crystal structure of graphite. For diffraction investigations, this layer spacing offers the perfect periodic structure. Because graphite has a reasonably broad interlayer spacing, it can be used for moderately energetic electron diffraction investigations. Because graphite has little background scattering, most of the diffraction signal comes from the crystal lattice rather than from defects or impurities.**