Full Report, Lab 3A: Electron Diffraction

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The goal of this lab was to provide further evidence for the particle-wave duality nature of the electron. To achieve this, we used a evacuated apparatus, with a phosphor coated end since the electrons excite the phosphor, causing it to glow green, and see a diffraction pattern caused by the ploycrystalline carbon film. The spacings on the diffraction pattern were then measured, and checked against the expected value. The values for the lattice spacings were $d_{10} = 0.105925 \pm 0.00038$ nm (95% CI) and $d_{11} = 0.09091 \pm 0.00020$ nm (95% CI) which were not within reasonable uncertainty of the expected values, as $d_{10} = 0.213$ nm and $d11 = 0.123$ nm.

I. INTRODUCTION

The electrons were boiled off and then accelerated through a high voltage potential then finally diffracted through a polycrystalline carbon film, all within an evacuated glass apparatus with a phosphor coating on the end. The phosphor glows green in the diffraction pattern of the electron, since the electron excites the phosphor coating, allowing us to measure the diffraction, and ultimately the spacing. Using calipers the measurements for each ring were taken. From this, we can show the wave-like nature of electrons, as they are diffracted through a grating, which only waves can do. We can compare with the expected diffraction using De Broglie's wavelength for an electron.

II. THEORETICAL MODEL

As shown in the diagram, the circular cross section of the sphere has a radius of $\frac{L}{2}$, thus using triangles inscribed within this circle, we can write the radius, y of any of the rings like so:

$$y^2 = \frac{L^2}{4} - x^2 \tag{1}$$

Let k be the diameter of the excited phosphor circle. We can then rewrite the expression in terms of k

$$\frac{k^2}{4} = \frac{L^2}{4} - x^2 \tag{2}$$

From here, we can now rewrite θ in terms of k

$$\sin(\theta) = \frac{k}{2\sqrt{(\frac{k}{2})^2 + \big(\frac{L}{2} + \sqrt{\frac{L^2}{4} - \frac{k^2}{4}}\big)}} \tag{3}$$

Using Bragg's Law:

$$n\lambda = 2d\sin(\theta) \tag{4}$$

We rewrite to solve for d, giving us:

$$d = \frac{n\lambda}{2\sin(\theta)} \tag{5}$$

Now, we solve for d in terms of k by substituting in $\sin(\theta)$ giving us:

$$d = \frac{n\lambda}{k}\sqrt{\frac{k^2}{4} + \Big(\frac{L}{2} + \sqrt{\frac{L^2}{4} - \frac{k^2}{4}}\Big)^2} \tag{6}$$

Using De Broglie's relation, in the case of an electron:

$$\lambda = \frac{h}{\sqrt{2ev_a}} \approx \frac{1.23}{\sqrt{v_a}} \text{ nm} \tag{7}$$

where v_a is the accelerating potential. Finally, we substitute this in to solve for d

$$d = \frac{n}{k}\Big(\frac{1.23 \times 10^{-9}}{\sqrt{v_a}}\Big)\sqrt{\frac{k^2}{4} + \Big(\frac{L}{2} + \sqrt{\frac{L^2}{4} - \frac{k^2}{4}}\Big)^2} \tag{8}$$

III. EXPERIMENT

A. Procedure

A high voltage power supply was connected to high accuracy voltmeter, and from the meter, it was connected to the apparatus. A dial varied the voltage, and the resulting size of the rings. Using calipers, the inner and outer diameters of the inner and outer rings were measured for each trial. The voltage was varied, and the experiment repeated, 13 times.

B. Data

*See attached tables for Raw data

IV. CONCLUSION

The values for the lattice spacings were $d_{10} = 0.105925 \pm 0.00038$ nm (95% CI) and $d_{11} = 0.09091 \pm 0.00020$ nm (95% CI) which were not within reasonable uncertainty of the expected values, as $d_{10} = 0.213$ nm (off by a factor of 2) and $d11 = 0.123$ nm (off by a factor of 1.4). The uncertainties for the diameters were calculated based on the manufacture's uncertainty of the

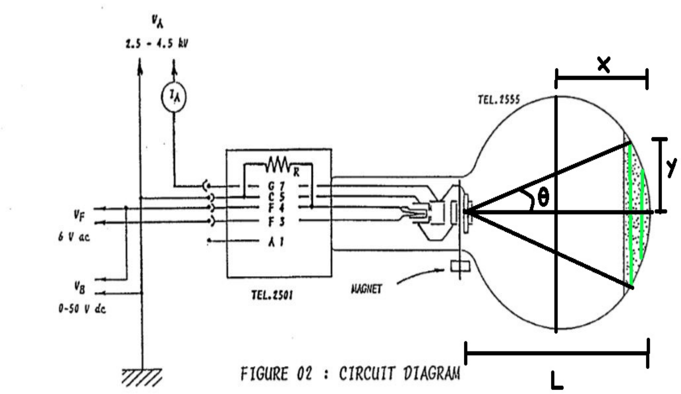

FIG. 1. A diagram of the setup for the lab. There is a glass apparatus, connected to power supplies and meters. There is a phosphor coat on the end of the glass apparatus

length of the tube and the voltage supply. The numbers were crunched out in Mathematica and Excel. However, a reason for the measurements not lining up with the expected value, is it became increasingly difficult to measure where the outer and inner diameters of the rings began as they became less intense and spread more. This could have significantly altered measurements, and thus increased the uncertainty by quite a bit.

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