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Experimental Design to Study the Effects of Low Intensity Magnetic on the Duality of Electron

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Abstract

With significant appraisals to the Original Double-Slit experiment, an audit of nature of electron is drafted. Electron has been proven to demonstrate unpredictable nature. It should behave as a particle, but it shows variations in behaviour when it is passed through two slits. In the experiment, photons (high-intensity light) are utilized as a detector, due to which interference pattern effectuates after detection. The wave-function is collapsed. A contemporary model is proposed, in which magnetic field of low-intensity is applied to canvass ever-changing nature of electron.

Keywords

Double-Slit Experiment, Quantum Duality, Measurements, QED, Electron

1. Introduction

The electron is one of many particles that exist at the sub-atomic level. Each particle is unique in its own way, with different properties and characteristics. But when the illustrious Double-slit experiment [1] was performed, it changed all we know about this tiny bit of matter. The double-slit experiment is regarded as the most beautiful experiment in physics, particularly Quantum Physics. In the experiment, the electron will display wave nature when it passes through two slits [2] [3] [4], as it will give wave pattern on detecting screen. When we attempt to measure their exact position, with high intensity light (photons) as detector [5], electron will cease its wave-nature [6] [7] [8], and behave, as was once expected, as a particle. Electron will bypass all expectations, as it changes its motion from wave (diffraction pattern) to particle nature (straight line). Therefore, the photons eliminate the wave-nature [9]. It provides rather flexible results, giving us a 50% probability of both wave and particle natures, and demonstrates that matter may have both expected particle-nature, as well as unexpected wave-nature. The phenomenon of duality is closely linked with the concepts of De-Broglie [10] hypothesis and compton effect [11]. In the recent study, a neutral field, composed of neutral Bosons, was proposed to elaborate on why the photons eliminate the wave-nature. In most of previous studies, no one has combined the magnetic deflection with double slit experiment to check for the duality of electron.

Now, with modified apparatus, we will introduce Low-Intensity magnetic field in the path of the beam of electrons. When beam is deflected, then we will use deflected electron-beam to perform a Double-slit experiment to investigate the effect of the field on the nature of electron. This is will verify either two conclusions: Either the wave-nature is reserved, or magnetic field is successful in accurately detecting electron without eliminating its wave nature. Or else, secondly, the wave-nature is collapsed once more, and magnetic-field is also unsuccessful in preserving wave-nature. In this proposal, the magnetic field will be at low-intensity.

2. Hypothesis

Considering that photons are utilized as detector, the act of measuring results in evident collapse of wave-function. Photons, as we are aware, are Quantized packets of energy [12] [13]. This quantized bundle of energy tends to interact with other quantum entities, which in this particular case, happens to be the free electrons. This interaction will collapse previously operational wave-function [14] [15]. Therefore, we have envisioned a goal to create such detectors that can evaluate location of electron at any given time, and, alongside, does not collapse wave-function. Therefore, such a specimen is put forward to look further into the impacts of Low-intensity Magnetic fields on nature of electron, and whether it will reveal a different result from detections via photons.

The research article proposes a unique study of the duality of electron. The results from proposed study might help in solving the enigma of role of observer in double slit experiment.

3. Theoretical and Practical Frame Work

We can produce free electrons by using Cathode ray tube (CRT's) [16] [17], or Thermionic emissions [18] [19] and electron gun [20] [21] to accelerate the electrons, and confine them into a beam.

Whenever a charged particle approaches a Magnetic field, it experiences a drag force that propels it towards and away South towards North pole of magnet, respectively. The force is calculated by Lorentz force law:

$$\boldsymbol{F} = q\left(\boldsymbol{E} + \boldsymbol{v} + \boldsymbol{B}\right) \tag{1}$$

where "F" is the force experienced by the particle, "q" is the charge of the particle, "E" is Electric field intensity and "B" is magnetic field intensity.

As the electric field in the setup is Zero we can rewrite Equation (1).

$$\boldsymbol{F} = q(\boldsymbol{v} + \boldsymbol{B}) \tag{1.1}$$

Figure 1 shows CRT and accelerating mechanism of an electron gun.

When potential difference is applied to CRT, the electrons are kicked out of atoms. These free electrons are then subjected to an Electrical field. This Electrical field is just for acceleration. The key to the experiment is to introduce a non-parallel Magnetic field. The applied field must be perpendicular to the path of the beam, so that the path of the beam is curved.

The velocity of the electron leaving the electron gun can be calculated:

As the kinetic energy is gained by the action of potential difference:

$$KE = \frac{1}{2} m_e v^2 \tag{2}$$

$$E = eV \tag{2.1}$$

By comparing Equation (2) with Equation (2.1),

$$\frac{1}{2} m_e v^2 = eV \tag{2.3}$$

$$v^2 = \frac{2eV}{m_e} \tag{2.4}$$

$$v = \sqrt{\frac{2eV}{m_e}} \tag{3}$$

The Equation (3) represents the velocity of the electrons leaving the electron gun.

Where "e" is the charge of electron [21] [22] [23], "V" is the applied voltage and "m_e" is the mass of the electron [24] [25] [26].

As the electrons are accelerated, we now need to introduce a Magnetic field to bend the beam of the electron, so that we can conform the interaction between the particle and the introduced field. A uniform Magnetic field is introduced, perpendicular to the motion of the beam of electrons. **Figure 2** illustrates the phenomena:

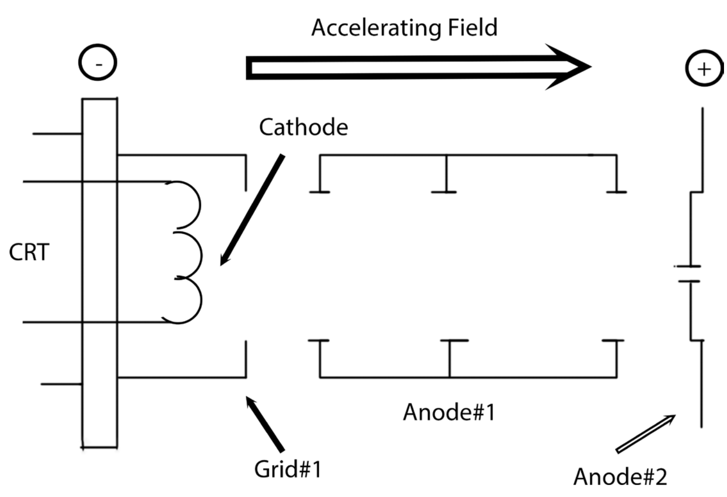

Figure 1. An electron gun and CRT as the source of electrons.

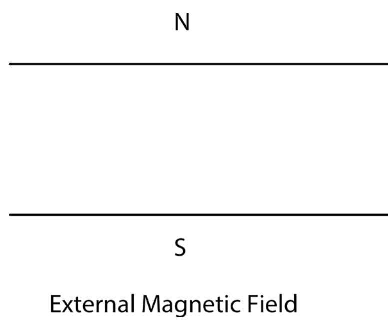

Figure 2. represents a uniform external magnetic field.

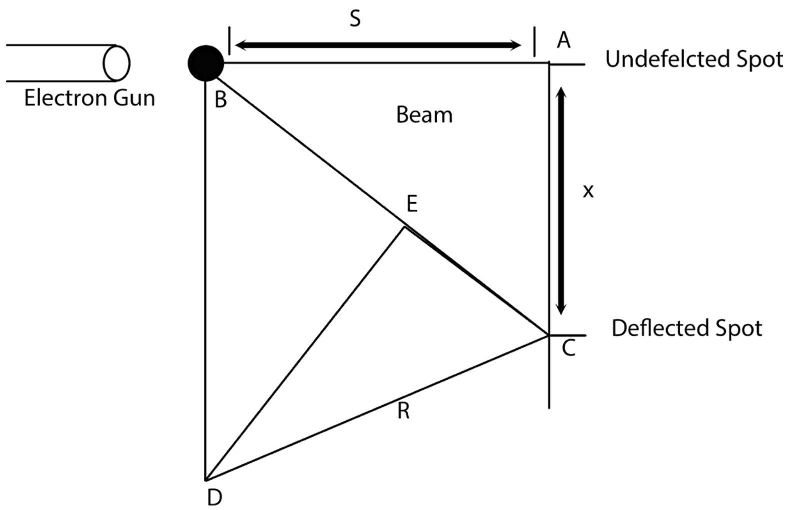

Figure 3. represents the path calculations.

The radius of the curve is given by Equation (4)

$$R = \frac{m}{eB}\sqrt{\frac{2eV_{acc}}{m}} \tag{4}$$

Figure 3 shows the defalcation mechanics.

If the magnetic field is uniform, the force will be constant and the radius of curvature, R, is fixed. We can use geometry to determine how R is related to measurable quantities.

ΔBAC is same as ΔDEB, since 2 sides are mutually perpendicular. Using the Pythagorean theorem.

$$\boldsymbol{BC}^2 = S^2 + x^2 \tag{4.1}$$

For similar triangles, the ratio of sides is equal. Also, $\boldsymbol{DE}$ bisects. $\boldsymbol{BC}$ Thus:

$$\frac{x}{\boldsymbol{BC}} = \frac{\boldsymbol{BE}}{R} = \frac{\frac{1}{2}\boldsymbol{BC}}{R} \tag{4.2}$$

Rearranging Equation (4.2)

$$2Rx = \boldsymbol{BC}^2 \tag{4.3}$$

Substituting the value from Equation (4.1)

$$R = \frac{S^2 + x^2}{2x} \approx \frac{S^2}{2x} \tag{4.4}$$

where "*S*" is size of the tube used and "*x*" is the deflection of the electron beam.

By substituting the value of "*R*" from Equation (4.4) in Equation (4) we find a preliminary expression for the deflection, *x*, in terms of the magnetic field strength:

$$\frac{S^2}{2x} \approx \frac{1}{B}\sqrt{\frac{2mV_{acc}}{e}} \tag{4.6}$$

As we cannot measure the strength of a magnetic field directly but we can relate the magnetic field to current "*I*" To simplify the math, we will make another approximation. The extreme oblong rectangular geometry of the coils used to generate the magnetic field, *B*, means that the two "far ends" contribute relatively little. As such, the coil can be thought of as two sets of *N* long wires, where *N* is the number of turns in the coil. The magnetic field generated by a *single* long straight wire:

$$B \approx \frac{\mu_\circ I}{2\pi a} \tag{4.7}$$

where *a* is the distance from the wire to the electron beam, *I* is the current which is generating *B*, and = $4\pi \times 10^{-7}$ Tesla·m/Amp.

As we have two poles thus we consider two coils. One at top and one at bottom.

Total magnetic field is given by

$$B_{Total} = B_{Top} + B_{Bottom} \tag{4.8}$$

$$B = N\left(\frac{\mu_\circ I}{2\pi a_{top}}\right) + N\left(\frac{\mu_\circ I}{2\pi a_{Bottom}}\right) = \frac{\mu_\circ I}{2\pi a} \tag{4.9}$$

By substituting the results from Equation (4.9) in Equation (4.6)

$$x = \frac{\mu_\circ N S^2 I \sqrt{\frac{e}{m}}}{2\sqrt{2}\pi a\sqrt{V_{acc}}} \tag{5}$$

Now, we modify the apparatus and swap the screen with the slits and at a distance, then we utilize a screen for the detection of the electron and study the wave-function **Figure 4** illustrates the scheme of the experiment.

As the study involves Low-intensity Magnetic fields, we are restricted to only micro to mili Tesla.

$$10^{-6} \to 10^{-3} \text{ Tesla}$$

4. Author contribution

A unique experimental design is proposed to study the duality of electron. If experimental evidence suggests that wave nature remains intact, then we might be able to develop such detectors capable of detecting the position without the interfering with the wave nature of fermions.

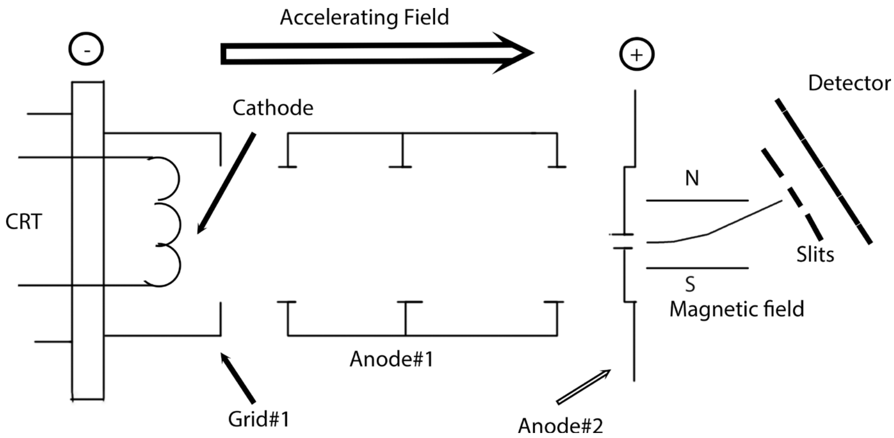

Figure 4. represents the final experimental scheme.

5. Conclusion

Based on given apparatus framework, we can investigate the implications of Magnetic field of Low-Intensity on nature of electron. There are two possible results: either wave nature is collapsed once more, or Magnetic field is, too, inept to measure locations of electron, or, the interference pattern is consistent, the only conclusion we can come to is that magnetic field is very much sufficient to measure locations of electron. Therefore, we could possibly be able to craft a particularly dedicated range of detectors that may coordinate the location of the electron without intrusion on its quantum nature of duality. Even if wave-function is collapsed, useful data for further modifications may be collected.

6. Discussions

The proposed design of the double slit experiment is a unique approach. If we succeed in the preservation of the wave function of the free electrons, it could open a whole new chapter for us to discover and the way we measure physical entities, such as quantum particles.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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