Intermediate Intensity Electrical Observer Effect

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Abstracts

The inspection of the dual nature of the electron is proposed, with modifications in initial double-slit experiment, such as introduction of intermediate-intensity of electrical field. We are mindful of mysterious nature of the quantum particles, exceptionally electrons. The particle maneuvers as wave, but upon observation, the wave-function of the electron is collapsed. An interference pattern ceases to be observed, which limits us to what we can measure and what we cannot, with current detection methods, in which photons are utilized as detector. In the original procedure, a source of high-intensity light (photons) is used to measure the position of the electrons, which leads to the collapse of the wave-function. An investigation is proposed, to observe the effects of the intermediate-intensity electric field on the nature of electron.

Keywords: double-slit experiment, quantum duality, measurements, QED, electron

Introduction

The bewildering nature of electron was unveiled in the light of the notorious Double-Slit experiment [1]. It is regarded as the most beautiful experiment in physics. The experiment gives rise to flexible results, which are contingent on the measurements to be taken. In this experiment, our eyes are opened to the fact that both light and matter are able to display characteristics of both classically-defined waves, and particles. It displays, with unparalleled strangeness, the fundamentally probabilistic nature of quantum mechanical phenomena. In said experiment, a beam of electrons passes through the two slits, after which interference pattern is detected [2,3,4] which describes the electrons as waves. Albeit, a peculiar phenomenon takes place when we wish to measure the position of the electron, so as to authenticate from which slit the electron went through; the interference pattern collapses [5,6,7] From here on, electrons are described as particles. The very act of measuring this quantum system has a profound effect on it. In the double-slit experiment, a high-intensity light source is used as a detector, which interferes with the state of electron [10]. The duality of electron is also linked to DE-Broglie hypothesis [8]. There is another phenomenon involved, such as

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Compton effect, [9] which transpires while measuring the position of the electron.

Recently, an impertinent model was coined to elucidate the interaction of the detector's photons and electron, [10] which will explicate the role of observer. Based on given observations, we have realized that using photons as detector will not yield any positive results. [11]. Therefore, a new approach is needed towards the apparatus of the double slit experiment, with some alterations. Alongside these alterations, we might be able to measure the position of the free electron, without interfering with the dual nature of the electron. We wish to use electric field with intermediate-intensity, instead of photons, to measure the position of the free electrons. This will confirm whether detector (electrical field) collapses the wave-function of electron, like the photons do, or not.

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 Intermediate-intensity electric fields on nature of electron, and whether it will reveal a different result from detections via photons.

Theoretical and Practical Frame

We can produce free electrons by using Cathode ray tube (CRT's) [16,17,] or Thermionic emissions [26,27] and electron gun [18,19] to accelerate the electrons, and confine them into a beam. Whenever a charged particle approaches an electrical field, it experiences a drag force that propels it towards and away from the positive to negative plates, respectively. The force is calculated by formula:

$$\vec{F} = q\vec{E} \text{ ---(1)}$$

Where "F" is the force experienced by the particle, "q" is the charge of the particle and "E" is electrical field intensity.

Figure (1) shows CRT and accelerating mechanism of an electron gun:

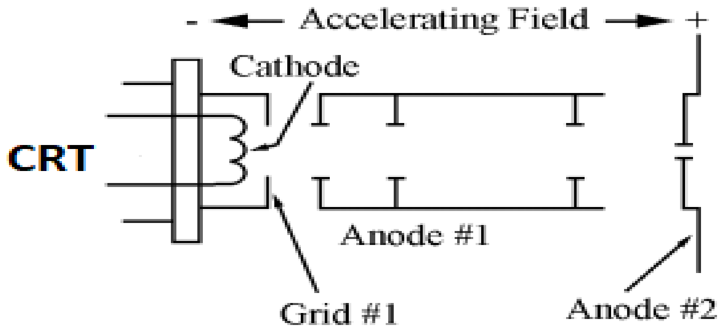


Figure (1)

When potential difference is applied to CRT, the electrons are kicked out of atoms. These free electrons are then subjected to a electrical field. This electrical field is just for acceleration. The key to the experiment is to introduce a non-parallel electrical 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:

$$KE = \frac{1}{2} m_e v^2 \quad \text{---(2)}$$

$$E = eV \quad \text{---(2.1)}$$

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

$$\frac{1}{2} m_e v^2 = eV \quad \text{---(2.3)}$$

$$v^2 = \frac{2eV}{m_e} \quad \text{---(2.4)}$$

$$v = \sqrt{\frac{2eV}{m_e}} \quad \text{---(3)}$$

The equation (3) represents the velocity of the electrons leaving the electron gun.
Where "e" is the charge of electron [20,21,22], "V" is the applied voltage and "m_e" is the mass of the electron [23,24,25].

As the electrons are accelerated, we now need to introduce an electrical field to bend the beam of the electron, so that we can conform the interaction between the particle and the introduced field. An uniform electric field is introduced, perpendicular to the motion of the beam of electrons. Figure (2) illustrates the phenomena:

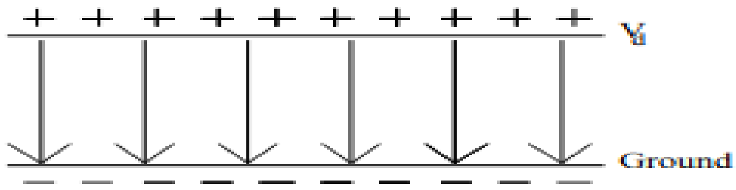


Figure (2)

The field strength is given as:

$$E_{\circ} = \frac{kq}{d^2} \quad \text{---(4)}$$

As the electric field is constant, we can use equation:

$$E_{\circ} = \frac{V}{d} \quad \text{---(4.1)}$$

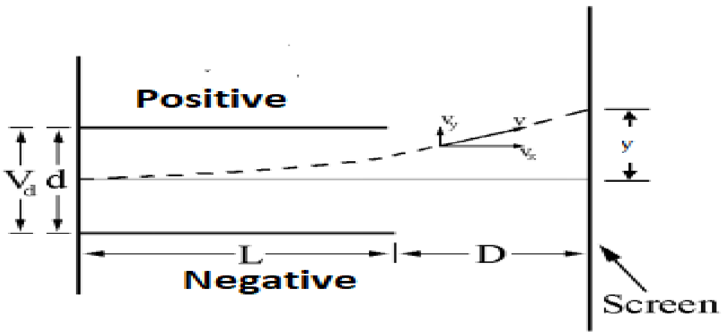


Figure (3)

By using kinematics and new 2nd equation of motion, we can calculate the deviation of the path of electron, due to the induced electric field:

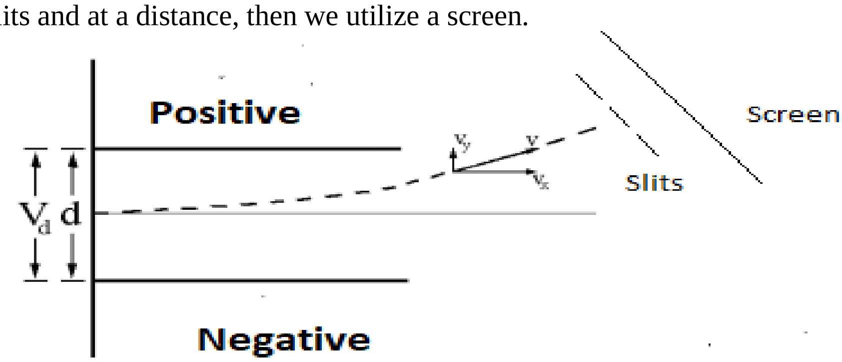
$$Y = \frac{eEL}{mv^2}\left(D + \frac{L}{2}\right) \quad \text{---(5)}$$

As the induced electric field is perpendicular to the path of electron:

$$E_{\circ} = \frac{V}{d} \quad \text{---(4.1)}$$

$$Y = \frac{eVL}{mv^2 d}\left(D + \frac{L}{2}\right) \quad \text{----(6)}$$

Now, we modify the apparatus and swap the screen with the slits and at a distance, then we utilize a screen.



(Figure: 4)

As the study involves Intermediate-intensity electric fields, we are restricted to Intermediate voltages only

$$\lim_{100}^{1000} V$$

Equations and Derivations

To solve the stated problems, we use Schrodinger wave equation

$$\frac{-h^2}{8\pi^2 m}\psi.\nabla^2 + U\psi = E\psi \text{ ---(7)}$$

As

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

As the electron moves in straight line, we consider that electron is moving along x-axis only thus the Laplace operator reduces to

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + 0 + 0 = \frac{\partial^2}{\partial x^2}$$

We can rewrite the equation (1)

$$\frac{-h^2}{8\pi^2 m}\frac{\partial^2 \psi}{\partial x^2} + U\psi = E\psi \text{ -----(7.1)}$$

It can be seen the equation (7.1) has the same form as the Schrodinger wave equation for particle in a box 1D.
Thus, we can use same wave function
$\psi = A\sin kx$

Where $k = \frac{n\pi}{a}$ ------(x)
Where $a \rightarrow \lambda$

Unlike particle in one dimension we make some adjustments, these adjustments come in the form of postulates,
1) Even free electrons are considered but the potential energy of the electron is not zero, the non-zero potential energy is due to the fact "Electron as energy carrier", Thus the potential energy is nothing but the ionization potential energy or the work function of the metal used as source in electron gun.
2) "a" in equation "x" is to be replaced with wave length of the moving electron as the electron is fired from electron gun, we consider the wave length as a discreet box where the electron exists for a period of time and then moves to second one i.e. From one wave length to another, thus energy can be defined at any point wavelength. To find wavelength we use De Broglie hypothesis

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

But we know that $\vec{p} = m_e\vec{v}$

We can re write DE Broglie equation.

$$\lambda = \frac{h}{m_e\vec{v}}$$

Putting the value of λ into equation(x)

$$k = \frac{n\pi . m_e \vec{v}}{h}$$

Now we have modified wave function

$$\psi = A\sin\left[\frac{n\pi . m_e \vec{v}}{h}\right]x$$

Now we solve the equation to find the solution

$$\frac{-h^2}{8\pi^2 m}\frac{\partial^2\psi}{\partial x^2} + U\psi = E\psi$$

To find the solution we take partial derivative with respect to “x”

$$\psi = A\sin\left[\frac{n\pi . m_e \vec{v}}{h}\right]x$$

$$\frac{\partial\psi}{\partial x} = \frac{\partial A\sin\left[\frac{n\pi . m_e \vec{v}}{h}\right]x}{\partial x}$$

$$\frac{\partial\psi}{\partial x} = \left[\frac{n\pi . m_e \vec{v}}{h}\right]A\cos\left[\frac{n\pi . m_e \vec{v}}{h}\right]x$$

We take partial derivative again,

$$\frac{\partial^2\psi}{\partial x^2} = \frac{\partial\left[\frac{n\pi . m_e \vec{v}}{h}\right]A\cos\left[\frac{n\pi . m_e \vec{v}}{h}\right]}{\partial x}x$$

$$\frac{\partial^2\psi}{\partial x^2} = -\left[\frac{n\pi.m_e\vec{v}}{h}\right]^2 A\sin\left[\frac{n\pi.m_e\vec{v}}{h}\right]x \text{ --------(y)}$$

As we know,

$$\psi = A\sin\left[\frac{n\pi.m_e\vec{v}}{h}\right]x$$

Thus we can rewrite equation (y)

$$\frac{\partial^2\psi}{\partial x^2} = -\left[\frac{n\pi.m_e\vec{v}}{h}\right]^2 \psi \text{ ------(p)}$$

Substituting equation "p" in Schrodinger wave equation (7.2)

$$-\left[\frac{n^2\pi^2 m_e^2 \vec{v}^2}{h^2}\right]\psi \frac{-h^2}{8\pi^2 m} + U\psi = E\psi$$

$$\psi\left(\left[\frac{n^2\pi^2 m_e^2 \vec{v}^2}{h^2}\right]\frac{h^2}{8\pi^2 m} + U\right) = E\psi$$

$$E = \frac{n^2 m_e \vec{v}^2}{8} + U \text{ --------(N)}$$

As we use Electric potential energy to accelerate electrons the the kinetic energy can be related to Electric potential energy.

$$m_e \vec{v}^2 = 2eV$$

Where "e" is elementary charge and "V" is Voltage

Substituting the value in equation (N)

$$E = \frac{n^2 eV}{4} + U \text{ ------(F)}$$

Recall 1st Postulate from the theory, the potential energy of the free electron is equal to Ionization Potential energy, thus.

$$U = \frac{(Z_{eff})^2 e^4 m_e}{4\varepsilon_\circ^2 n^2 h^2}$$

Substituting "U" in equation (F)

$$E = \frac{n^2 eV}{4} + \frac{(Z_{eff})^2 e^4 m_e}{4\varepsilon_\circ^2 n^2 h^2} \text{---------(I)}$$

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.

Conclusion

Based on given apparatus framework, we can investigate the implications of electric field of Intermediate-Intensity on nature of electron. There are two possible results: either wave nature is collapsed once more, and electric field is, too, inept to measure location of electron, or, the interference pattern is consistent, the only conclusion we can come to is that electric field is very much sufficient to measure location 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. We can end up with two results

No observer

$$E = \frac{n^2 eV}{4} + \frac{(Z_{eff})^2 e^4 m_e}{4\varepsilon_\circ^2 n^2 h^2}$$

Observer

$$E = \frac{n^2 eV}{4}$$

Either the indeterminate intensity electric field acts as an observer and the wave function is collapsed or it might not the effect the duality of electron and the wave function is preserved.

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