Open Access Library Journal
2025, Volume 12, e13833
ISSN Online: 2333-9721
ISSN Print: 2333-9705

The Discovery of a New Type of Wave Form: A Study on the Genesis of de Broglie Waves

Yicheng Chen

College of Physical Science and Technology, Central China Normal University, Wuhan, China
Email: cyc4618@163.com

How to cite this paper: Chen, Y.C. (2025) The Discovery of a New Type of Wave Form: A Study on the Genesis of de Broglie Waves. *Open Access Library Journal*, **12**: e13833.
https://doi.org/10.4236/oalib.1113833

Received: June 24, 2025
Accepted: August 22, 2025
Published: August 25, 2025

Abstract

This article aims to reveal the truth behind the formation of de Broglie waves and clarify the mysterious assumptions such as wave-particle duality and probability waves, which people are familiar with but do not understand the reasons behind. On the towering tree of physics, the branch concerning the interpretation of de Broglie waves has grown crooked! This article intends to sprout new buds at this node to promote the progress and prosperity of physics! Based on the electric field force that electrons experience in a cathode ray tube and the continuity equation of electrons, under assumptions such as the non-elastic approximation, this article proves that wave-particle duality is actually the macroscopic movement of microscopic particles in the form of waves. Theoretically, it is demonstrated that the transverse component of the electron's velocity in the tube satisfies a nonlinear inhomogeneous wave equation. The equations of this type should describe a complex system: under certain parameters, the system may be extremely sensitive to initial conditions, showing chaotic characteristics, and its output is extremely complex and difficult to predict over the long term. This is the uncertainty in quantum mechanics! The conclusion of this article indicates that this is a new form of wave, that is, the form of waves not only includes the propagation of vibrations but also the macroscopic movement of microscopic particles in the form of waves. Therefore, this wave can transport material particles from one end to the other in the form of waves! Moreover, this article discusses a single electron, so even if the electrons are emitted one by one, their wave characteristics can still be observed on the screen! From the discussion in this article, it can be seen that there are still some problems with the movement of electrons in the cathode ray tube that need to be solved in order to further explore the special movement laws of electrons in the cathode ray tube from both theoretical and experimental aspects. At the same time, it is hoped that the theory in this article can provide theoretical guidance for the manufacture and debugging of electron microscopes and the design of large-scale integrated circuits, thereby influencing other related fields. The involved technological fields will be huge and extensive! It is hoped that this article can attract the attention of many colleagues in the physics community and work together to deeply analyze the objective truth of wave-particle duality presented by the movement of microscopic particles, in order to promote the progress and prosperity of physics. Finally, the essential differences between the conclusions of this article and the Schrödinger equation are discussed, and it is proved that the movement of microscopic particles in a constant electric field is not the simple harmonic motion as Schrödinger claimed. Moreover, the key words of wave-particle duality are wave and particle, and the key words of this article are the same. Therefore, the physical phenomena that wave-particle duality can explain should also be explainable by the conclusion of this article!

Subject Areas

Theoretical Physics

Keywords

De Broglie Wave, Newtonian Dynamics, Wave Equation, Schrödinger Equation

1. Introduction

Since de Broglie proposed the hypothesis of matter waves, many physicists have conducted experiments to verify this hypothesis and obtained some meaningful results. As a result, matter waves have gained widespread recognition in the field of physics, and a series of mysterious hypotheses such as wave-particle duality and probability waves have been derived from it. At the same time, a series of strange theories have also emerged. This article aims to distinguish the true from the false and uncover the truth of de Broglie waves, in order to promote the progress and prosperity of physics!

2. The Electric Field Force on an Electron and Its Continuity Equations Are Deduced Theoretically

In 1927, Clinton-Davidson and Lester Germer first detected matter waves using an electron diffraction device (including an electron gun, nickel crystal and detector). For the convenience of discussion, here we will discuss this issue with the aid of cathode ray tubes equipped with special devices (such as crystal targets or double-slit devices). Cathode ray tubes come in various models and have a rather complex internal structure. Besides the basic filament, cathode and anode, there are also focusing coils, deflection coils and the crystal target or double-slit device mentioned earlier, as shown in Figure 1. However, the various components mentioned in the latter are set up to obtain high-quality images. These are components set up at the technical level to change the overall movement path of electrons and have nothing to do with the theoretical research here. Therefore, we will simplify the cathode ray tube as shown in Figure 2.

Suppose the cathode ray tube (hereinafter referred to as the tube) is placed horizontally along the x-axis, with the central axis of the tube overlapping the x-axis of the rectangular coordinate system. We first discuss the movement law of electrons between the rear accelerating anode and the second anode. Let the z-axis pass through the right side of the rear accelerating anode. The coordinate origin $x=0$ is shown in the figure. The x-coordinate of the second anode is $x=L$, and the x-coordinate of any point in this area is $x=l$, $0<l\le L$. It can be imagined that the electron beam in the tube is axially symmetrical about the x-axis, and the envelope of the electron beam is a cone. Take any plane through the x-axis as the x-z plane. At this time, the velocity $\boldsymbol{\upsilon}=\{\upsilon_x,\upsilon_y,\upsilon_z\}$ of the electron, due to the very small mass of the electron, can be considered to move only within the x-z plane under the action of the applied voltage. Therefore, $\upsilon_y=0$.

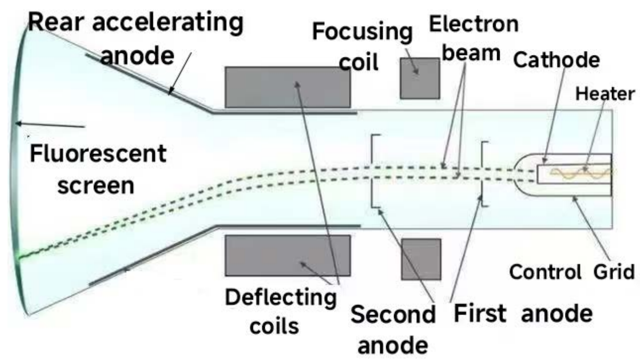

Figure 1. Schematic diagram of the cathode ray tube.

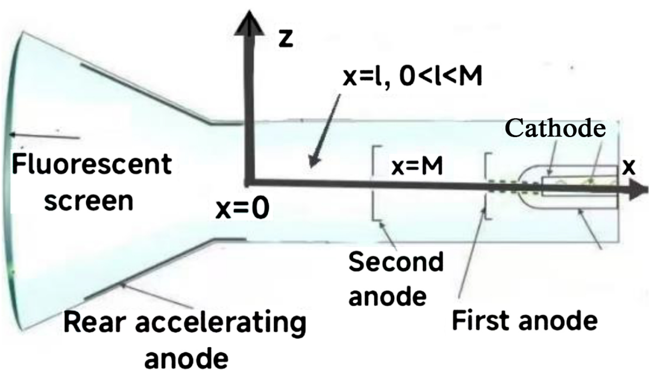

Figure 2. Simplified diagram of the cathode ray tube.

Let there be n electrons per unit volume in the tube. Therefore, the mass density of the electrons in the tube is $\rho=nm_e$, where m_e represents the mass of a single electron, and the charge density is $q=ne=-n|e|$, where e is the electron charge, and $e<0$, where $|e|$ is the absolute value of the electron charge. In a rectangular coordinate system, the equation of motion is:

$$nm_e \frac{\mathrm{d}\boldsymbol{\upsilon}}{\mathrm{d}t} = \sum_i \boldsymbol{F}_i \tag{1}$$

where $\boldsymbol{F}_i$ represents various external forces.

Here, we consider only the motion law of the z component of electron velocity. At $x=0$, the electric potential $-u=-u_1$, $u_1>0$, At $x=l$, $0<l\le L$, the electric potential is $-u$, $u>0$, and at $x=L$, the electric potential is $-U$, where $U>0$. Due to the geometric structure of the cathode ray tube, the equipotential surfaces of the electric field within the tube are not planar. At $x=l$, the electric field strength should have a z component, whose value is $E_z = -\frac{\partial(-u)}{\partial z} = \frac{\partial u}{\partial z}$. The z component of the electric field force acting on these electrons is:

$$F_z = neE_z = -n|e|\frac{\partial u}{\partial z} \tag{2}$$

Let the component of the gravitational acceleration g in the x-z plane be g_z. In the rectangular coordinate system, the z component of equation (1) is:

$$nm_e \frac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -n|e|\frac{\partial u}{\partial z} - nm_e g_z$$

By eliminating the common factor n from the equation, we obtain:

$$m_e \frac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -|e|\frac{\partial u}{\partial z} - m_e g_z \tag{3}$$

Obviously, this equation describes the motion of a single electron.

As is well known, the order of magnitude of the electron charge is 10^{-19}, and the order of magnitude of the electron mass is 10^{-31}. Since $g_z < 10$, a preliminary estimate $\partial u/\partial z = E_z < 10^3$ gives the ratio of the magnitudes of gravitational force to electric field force acting on the electron as:

$$m_e g_z \Big/ \left(|e|\frac{\partial u}{\partial z}\right) = \frac{m_e}{|e|}\cdot\frac{g_z}{E_z} \sim \frac{10^{-31}}{10^{-19}}\cdot\frac{g_z}{E_z} = 10^{-12}\frac{10}{10^3} \approx 10^{-14} \ll 1$$

Therefore, relative to the electric field force, the gravitational force acting on the electron is negligible, so equation (3) simplifies to:

$$m_e \frac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -|e|\frac{\partial u}{\partial z} \tag{4}$$

The mass density of electrons in the tube is ρ, and the continuity equation $\partial\rho/\partial t + \nabla\cdot(\rho\boldsymbol{\upsilon}) = 0$ for the electrons can be expressed as:

$$\frac{\mathrm{d}\rho}{\mathrm{d}t} + \rho\,\mathrm{div}\,\boldsymbol{\upsilon} = 0 \tag{5}$$

In the rectangular coordinate system, formula (5) can be written as:

$$\frac{\mathrm{d}\ln\rho}{\mathrm{d}t} + \left(\frac{\partial\upsilon_x}{\partial x} + \frac{\partial\upsilon_z}{\partial z}\right) = 0,\ \upsilon_y = 0 \tag{6}$$

Under the action of a constant voltage, although the electron density at various points in the tube fluctuates occasionally, it basically does not change much. As an original fundamental theoretical research, the methods adopted are all to focus on the main issues and ignore the secondary factors! Therefore, we assume that the electron flow in the tube is incompressible, which is the $\rho = \text{constant}$, indicating that the first term in equation (6) is zero [1]; Further speaking, even if the mass density of electrons is considered to be variable and the first term in Equation (6) is not zero, what is discussed in this paper is the equation satisfied by the υ_z component of the electron's velocity. The result obtained is still a wave equation, only that this wave equation has an additional non-homogeneous term generated by the first term in Equation (6)! Experimental physicists all know that the grid potential in a cathode-ray tube is used to control the number of emitted electrons. When this potential is highly stable, it can be assumed that the electron mass density ρ at each point in the tube is a constant that does not change with time. We will discuss our topic under this ideal condition. Based on this consideration, we regard $\rho = \text{constant}$, and thus Equation (6) becomes:

$$\frac{\partial \upsilon_x}{\partial x} + \frac{\partial \upsilon_z}{\partial z} = 0 \tag{7}$$

At the rear acceleration anode $x = 0$, which is considered the ideal rigid body, the electron velocity satisfies:

$$\upsilon_x\big|_{x=0} = \upsilon_{x3} \tag{8}$$

Thus, combining equations (4) and (7), the basic equations of electron motion in the tube are:

$$\begin{cases} m_e \dfrac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -|e| \dfrac{\partial u}{\partial z}, \\ \dfrac{\partial \upsilon_x}{\partial x} + \dfrac{\partial \upsilon_z}{\partial z} = 0. \end{cases} \tag{9}$$

To proceed with the discussion, let us analyze the characteristics of possible solutions that satisfy equation (7). In a long and narrow ray tube, the electric field force along the direction of z should not change significantly with the coordinate x. As a basic research, it can be considered that υ_z is independent of the coordinate x, that is, $\partial \upsilon_z / \partial z$ is independent of the coordinate x! Specific solutions that meet this requirement can be found, but we will use mathematics to investigate solutions that meet the physical conditions here. y utilizing the assumption that $\partial \upsilon_z / \partial z$ is independent of the x coordinate and applying the boundary condition given in equation(8), we can transform equation (7).

To proceed, we integrate the continuity equation from equation (7) over the interval $x = 0$ to $x = l$:

$$\int_0^l \frac{\partial \upsilon_x}{\partial x} \delta x + \int_0^l \frac{\partial \upsilon_z}{\partial z} \delta x = 0$$

Use the formula (8), and noting that $\partial \upsilon_z / \partial z$ is independent of x, we obtain

$$\upsilon_{xl} = \upsilon_{x3} - l \frac{\partial \upsilon_z}{\partial z} \tag{10}$$

Meanwhile, the x-component of the electron's velocity is:

$$\upsilon_{xl} \equiv \upsilon_x\big|_{x=l} = \frac{\mathrm{d}l}{\mathrm{d}t} \tag{11}$$

Combining equations (11) and (10), we arrive at:

$$\frac{\partial l}{\partial t} + \upsilon_z \frac{\partial l}{\partial z} + l\frac{\partial \upsilon_z}{\partial z} - \upsilon_{x3} = 0 \tag{12}$$

Combining equations (4) and (12), the equations governing electron motion in the tube can be expressed as:

$$\begin{cases} m_e \dfrac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -|e|\dfrac{\partial u}{\partial z}, \\ \dfrac{\mathrm{d}l}{\mathrm{d}t} + l\dfrac{\partial \upsilon_z}{\partial z} - \upsilon_{x3} = 0. \end{cases} \tag{13}$$

In equation(13), each term of the first formula is multiplied by l/m_e, and each term of the second formula is multiplied by $u|e|/m_e$, yielding:

$$\begin{cases} l\dfrac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = -|e|\dfrac{l}{m_e}\dfrac{\partial u}{\partial z}, \\ \dfrac{|e|u}{m_e}\dfrac{\mathrm{d}l}{\mathrm{d}t} + l\dfrac{|e|u}{m_e}\dfrac{\partial \upsilon_z}{\partial z} - \dfrac{|e|u\upsilon_{x3}}{m_e} = 0. \end{cases} \tag{14}$$

Using

$$\begin{cases} l\dfrac{\mathrm{d}\upsilon_z}{\mathrm{d}t} = \dfrac{\mathrm{d}(l\upsilon_z)}{\mathrm{d}t} - \upsilon_z\dfrac{\mathrm{d}l}{\mathrm{d}t}, \\ \dfrac{l|e|}{m_e}\dfrac{\partial u}{\partial z} = \dfrac{|e|}{m_e}\dfrac{\partial(lu)}{\partial z} - \dfrac{|e|u}{m_e}\dfrac{\partial l}{\partial z}, \\ \dfrac{|e|u}{m_e}\dfrac{\mathrm{d}l}{\mathrm{d}t} = \dfrac{|e|}{m_e}\dfrac{\mathrm{d}(lu)}{\mathrm{d}t} - \dfrac{|e|l}{m_e}\dfrac{\mathrm{d}u}{\mathrm{d}t}, \\ \dfrac{|e|lu}{m_e}\dfrac{\partial \upsilon_z}{\partial z} = \dfrac{|e|u}{m_e}\dfrac{\partial(l\upsilon_z)}{\partial z} - \upsilon_z\dfrac{|e|u}{m_e}\dfrac{\partial l}{\partial z}. \end{cases}$$

Additionally, since the applied voltage is constant, the potential u at each point in the tube is independent of time t, that is, $\mathrm{d}u/\mathrm{d}t = 0$. Therefore, equation (14) can be rewritten as:

$$\begin{cases} \dfrac{\mathrm{d}(l\upsilon_z)}{\mathrm{d}t} - \upsilon_z\dfrac{\mathrm{d}l}{\mathrm{d}t} = -\dfrac{|e|}{m_e}\dfrac{\partial(lu)}{\partial z} + \dfrac{|e|u}{m_e}\dfrac{\partial l}{\partial z}, \\ \dfrac{|e|}{m_e}\dfrac{\mathrm{d}(lu)}{\mathrm{d}t} + \dfrac{|e|u}{m_e}\dfrac{\partial(l\upsilon_z)}{\partial z} - \upsilon_z\dfrac{|e|u}{m_e}\dfrac{\partial l}{\partial z} - \dfrac{|e|u\upsilon_{x3}}{m_e} = 0. \end{cases} \tag{15}$$

Next, we simplify equation (15). Considering that the overall motion of the electron beam in the tube is directed toward the anode, there is no convection or other complex movements. Therefore, the following simplification is both reasonable and feasible. Replacing $\dfrac{\mathrm{d}}{\mathrm{d}t} = \dfrac{\partial}{\partial t} + \boldsymbol{\upsilon}\cdot\mathrm{grad}$ with $\dfrac{\partial}{\partial t}$ in this formula effectively ignores the nonlinear term in $\dfrac{\mathrm{d}}{\mathrm{d}t}$, meaning that the convection and transport of energy flow are not considered. However, the conversion of various forms of energy within the volume V is not affected [1]. As a result, $\frac{\mathrm{d}}{\mathrm{d}t}$ is replaced by $\frac{\partial}{\partial t}$, and equation (15) becomes:

$$\begin{cases} \frac{\partial(l\upsilon_z)}{\partial t} - \upsilon_z \frac{\partial l}{\partial t} = -\frac{|e|}{m_e}\frac{\partial(lu)}{\partial z} + \frac{|e|u}{m_e}\frac{\partial l}{\partial z}, \\ \frac{|e|}{m_e}\frac{\partial(lu)}{\partial t} + \frac{|e|u}{m_e}\frac{\partial(l\upsilon_z)}{\partial z} - \upsilon_z \frac{|e|u}{m_e}\frac{\partial l}{\partial z} - \frac{|e|u\upsilon_{x3}}{m_e} = 0. \end{cases} \tag{16}$$

In equation(16), each term of the first formula is differentiated partially with respect to time t, and each term of the second formula is differentiated partially with respect to the coordinate z, yielding:

$$\begin{cases} \frac{\partial^2(l\upsilon_z)}{\partial t^2} - \frac{\partial}{\partial t}\left(\upsilon_z \frac{\partial l}{\partial t}\right) = -\frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t} + \frac{|e|}{m_e}\frac{\partial}{\partial t}\left(u\frac{\partial l}{\partial z}\right), \\ \frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t} + \frac{|e|}{m_e}\frac{\partial}{\partial z}\left[u\frac{\partial(l\upsilon_z)}{\partial z}\right] - \frac{|e|}{m_e}\frac{\partial}{\partial z}\left(u\upsilon_z\frac{\partial l}{\partial z}\right) - \frac{|e|\upsilon_{x3}}{m_e}\frac{\partial u}{\partial z} = 0. \end{cases}$$

Calculate the second term on the left side of the equal sign of the next equation in the upper system of equations, and we get:

$$\begin{cases} \frac{\partial^2(l\upsilon_z)}{\partial t^2} - \frac{\partial}{\partial t}\left(\upsilon_z \frac{\partial l}{\partial t}\right) = -\frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t} + \frac{|e|}{m_e}\frac{\partial}{\partial t}\left(u\frac{\partial l}{\partial z}\right), \\ \frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial t\partial z} + \frac{|e|u}{m_e}\frac{\partial^2(l\upsilon_z)}{\partial z^2} + \frac{|e|}{m_e}\frac{\partial u}{\partial z}\left[\frac{\partial(l\upsilon_z)}{\partial z}\right] - \frac{|e|}{m_e}\frac{\partial}{\partial z}\left(u\upsilon_z\frac{\partial l}{\partial z}\right) - \frac{|e|\upsilon_{x3}}{m_e}\frac{\partial u}{\partial z} = 0. \end{cases} \tag{17}$$

In equation (17), we define

$$c^2 \equiv \frac{|e|u}{m_e} \tag{18}$$

Then, by using Equation (18) and paying attention to $\mathrm{d}u/\mathrm{d}t = 0$, Equation (17) becomes:

$$\begin{cases} \frac{\partial^2(l\upsilon_z)}{\partial t^2} - \frac{\partial}{\partial t}\left(\upsilon_z \frac{\partial l}{\partial t}\right) = -\frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t} + c^2\frac{\partial}{\partial t}\left(\frac{\partial l}{\partial z}\right), \\ \frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial t\partial z} + c^2\frac{\partial^2(l\upsilon_z)}{\partial z^2} + \frac{|e|}{m_e}\frac{\partial u}{\partial z}\left[\frac{\partial(l\upsilon_z)}{\partial z}\right] - \frac{|e|}{m_e}\frac{\partial}{\partial z}\left(u\upsilon_z\frac{\partial l}{\partial z}\right) - \frac{|e|\upsilon_{x3}}{m_e}\frac{\partial u}{\partial z} = 0. \end{cases} \tag{19}$$

Solving for $\frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t}$ using the preceding formula in equation (19), we obtain:

$$\frac{|e|}{m_e}\frac{\partial^2(lu)}{\partial z\partial t} = c^2\frac{\partial}{\partial t}\left(\frac{\partial l}{\partial z}\right) - \frac{\partial^2(l\upsilon_z)}{\partial t^2} + \frac{\partial}{\partial t}\left(\upsilon_z\frac{\partial l}{\partial t}\right) \tag{20}$$

Newton's perspective on time and space suggests that time coordinates and spatial coordinates are independent of one another. As a result, the order of derivation for a space-time function with respect to time and spatial coordinates can be interchanged; that is, $\frac{\partial^2(lu)}{\partial z\partial t} = \frac{\partial^2(lu)}{\partial t\partial z}$. According to this property, substitute equation (20) into the next equation in system of equations (19) and sort it out to obtain [2]:

$$\begin{aligned}&\frac{\partial^2(l\upsilon_z)}{\partial t^2}-c^2\frac{\partial^2(l\upsilon_z)}{\partial z^2}\\&=\frac{|e|}{m_e}\frac{\partial u}{\partial z}\left[\frac{\partial(l\upsilon_z)}{\partial z}\right]-\frac{|e|}{m_e}\frac{\partial}{\partial z}\left(u\upsilon_z\frac{\partial l}{\partial z}\right)+\frac{\partial}{\partial t}\left(c^2\frac{\partial l}{\partial z}+\upsilon_z\frac{\partial l}{\partial t}\right)\end{aligned}\tag{21}$$

The second-order partial derivative of the product of l and υ_z on the left-hand side of equation (21) is calculated. After sorting, the following can be obtained:

$$\frac{\partial^2\upsilon_z}{\partial t^2}-c^2\frac{\partial^2\upsilon_z}{\partial z^2}=\frac{|e|}{m_e}\frac{\partial u}{\partial z}\frac{\partial\upsilon_z}{\partial z}+c^2\left(\frac{\partial\ln l}{\partial z}\frac{\partial\upsilon_z}{\partial z}+\frac{1}{l}\frac{\partial^2 l}{\partial t\partial z}\right)-\frac{\partial\ln l}{\partial t}\frac{\partial\upsilon_z}{\partial z}\tag{22}$$

Obviously, equation (22) is the wave equation of the υ_z component of the electron's velocity in the tube. The wave of the transverse component of the electron's velocity is along the transverse direction of the ray tube, but this wave is a longitudinal wave along the transverse direction! The wave equation (22) indicates that the form of waves is not only the propagation of vibrations, but also the macroscopic motion of microscopic particles in the form of waves. Therefore, this kind of wave can transfer physical particles from one end to the other in the form of waves!

Furthermore, the second partial derivative of the last two terms on the right-hand side of equation (21) is calculated. After sorting, the following can be obtained:

$$\begin{aligned}\frac{\partial^2 l}{\partial t^2}-c^2\frac{\partial^2 l}{\partial z^2}=&\frac{1}{\upsilon_z}\left[\frac{\partial^2(l\upsilon_z)}{\partial t^2}-c^2\frac{\partial^2(l\upsilon_z)}{\partial z^2}\right]+c^2\left(\frac{\partial\ln\upsilon_z}{\partial z}\frac{\partial l}{\partial z}-\frac{1}{\upsilon_z}\frac{\partial^2 l}{\partial t\partial z}\right)\\&-\frac{l|e|}{m_e}\frac{\partial u}{\partial z}\frac{\partial\ln\upsilon_z}{\partial z}-\frac{\partial\ln\upsilon_z}{\partial t}\frac{\partial l}{\partial t}\end{aligned}\tag{23}$$

Interestingly, the coordinate l of the electron movement in the tube also satisfies the wave equation. It is a transverse wave along the transverse direction, while the vibration direction is along the longitudinal direction!

In $c^2=|e|u/m_e$ of equation (18), $|e|u$ represents the potential energy obtained by an electron moving within the tube, and $|e|u/m_e$ is the square of the electron's velocity at the potential u. Equations (22) and (23) indicate that this is a nonlinear, non-homogeneous wave equation, where c is the wave velocity. From equation (18), we can see that the wave velocity is not constant but depends on the electric potential u at a certain point in the tube. Where u is large, the wave speed is high, where u is small, the wave speed is low. Among

$$c=\sqrt{\frac{|e|u}{m_e}}\ \mathrm{m\cdot s^{-1}}=175878.6\sqrt{u}\ \mathrm{m\cdot s^{-1}}\tag{24}$$

It is clear that electron fluctuations in the tube exhibit a transverse component. According to the wave velocity equation (24), when the particle's mass is large, the wave velocity decreases. If the mass increases beyond a certain threshold, the wave velocity can be considered zero. Therefore, massive particles do not exhibit wave properties during motion.

In the entire post-acceleration anode region, the electric potential is an equipotential body, and there is no electric field force here, that is, $\partial u/\partial z = 0$; It can be seen from Equation (24) that the wave velocity is a constant, and the wave equations (22) and (23) become:

$$\frac{\partial^2 \upsilon_z}{\partial t^2} - c^2 \frac{\partial^2 \upsilon_z}{\partial z^2} = c^2 \left(\frac{\partial \ln l}{\partial z} \frac{\partial \upsilon_z}{\partial z} + \frac{1}{l} \frac{\partial^2 l}{\partial t \partial z} \right) - \frac{\partial \ln l}{\partial t} \frac{\partial \upsilon_z}{\partial z} \tag{25}$$

$$\begin{aligned} \frac{\partial^2 l}{\partial t^2} - c^2 \frac{\partial^2 l}{\partial z^2} = \frac{1}{\upsilon_z} \left[\frac{\partial^2 (l\upsilon_z)}{\partial t^2} - c^2 \frac{\partial^2 (l\upsilon_z)}{\partial z^2} \right] \\ + c^2 \left(\frac{\partial \ln \upsilon_z}{\partial z} \frac{\partial l}{\partial z} - \frac{1}{\upsilon_z} \frac{\partial^2 l}{\partial t \partial z} \right) - \frac{\partial \ln \upsilon_z}{\partial t} \frac{\partial l}{\partial t} \end{aligned} \tag{26}$$

In this area, electrons fluctuate according to the rules of these two equations.

So, what is the movement pattern of electrons during the period when they leave the “post-accelerating anode” and reach the fluorescent screen? In fact, this area has neither electric field force nor electric potential. When the electron flies away from the “post-accelerating anode” area, the z component of the electron’s velocity maintains the fluctuation characteristics at the moment it left the “post-accelerating anode” area and performs inertial motion in this area (the functions of technical components such as the focusing coil and deflection coil are omitted). Electrons bring the wave characteristics of the front area to the fluorescent screen. Under the action of technical components such as the focusing coil and deflection coil, they hit the fluorescent screen, thus resulting in an interference or diffraction image of the wave.

As for the discussion of the regions between the cathode and the first anode, and between the first anode and the second anode, it is similar to the above discussion. The only difference is that the coordinate origins of each region are different, and the electric potentials at each coordinate origin are also different. Moreover, in equation (8), $\upsilon_x|_{x=0} = \upsilon_{x3}$ should be correspondingly changed to $\upsilon_x|_{x=0} = \upsilon_{x1}$ and $\upsilon_x|_{x=0} = \upsilon_{x2}$.

3. Conclusions and Prospects

We have assumed that the motion of electrons in the tube is symmetric about the x-axis. Therefore, in any plane passing through the x-axis, the velocity component of electrons in the direction perpendicular to the x-axis follows the wave behavior described by equation (22). Due to wave interference, electrons emitted to the screen produce a circular interference pattern. This means that electrons move macroscopically in a wave-like manner, and thus transfer from one end to the other in this form of movement! Furthermore, since we are considering individual electrons, even if the electrons are emitted one at a time, their fluctuating properties can still be observed on the screen.

As mentioned earlier, this paper focuses solely on the motion law of the transverse component of electron motion in the tube, leaving the longitudinal component for future investigation. Additionally, the wave speed exhibits unusual characteristics that require experimental verification, and it may also lead to unexpected physical effects. It is expected that the theory presented in this paper could offer valuable guidance for the development and calibration of electron microscopes [3], the design of large-scale integrated circuits and other applications [4], thus influencing related fields [4] and potentially impacting a wide range of scientific and technological fields.

4. The Difference between the Conclusions of This Paper and Those of the Schrödinger Equation

When it comes to matter waves, anyone who studies physics will immediately think of the Schrödinger equation. It naturally comes to mind: Isn't the Schrödinger equation simply a description of the wave characteristics of microscopic particles? Introducing another wave equation to describe the motion of microscopic particles is unacceptable, so people will reject the work of this paper.

In view of this, it is necessary to explain the essential difference between the conclusion of this article and the Schrödinger equation. Let's take a look at how the Schrödinger equation was obtained. It is well known that the Schrödinger equation was obtained by comparison with the linear homogeneous wave equation $\frac{\partial^2\psi}{\partial t^2} - c^2\frac{\partial^2\psi}{\partial z^2} = 0$ in classical physics. In classical physics, the partial derivative of the wave equation with respect to time t is second-order, whereas in the Schrödinger equation, the partial derivative with respect to time t is first-order. This mathematical form is similar to that of the heat conduction equation, whose solutions are not periodic. To achieve periodicity, Schrödinger introduced the first-order partial derivative of the wave function $\psi(\boldsymbol{x},t)$ with respect to time t multiplied by a factor $i = e^{\mathrm{i}\pi/2}$. This adjustment made the wave function $\psi(\boldsymbol{x},t)$ periodic, thereby describing wave-like properties. However, this formulation limits the Schrödinger equation to describing only linear homogeneous wave processes. This limitation is problematic—who has ever demonstrated that the motion of microscopic particles is always simple harmonic motion? The answer is; Surely no one has proven the problem! It can be seen that the Schrödinger equation cannot accurately describe the motion law of microscopic particles, and the wave characteristics described by it do not have a clear image, so there are such specious explanations as wave-particle duality, probability wave, and so on. The superficiality of Schrödinger's equation will not be discussed here, this paper adopts a well-established approach to scientific exploration—focusing on the main problem and ignoring secondary factors to obtain meaningful theoretical and instructional insights. By ignoring certain secondary factors, a wave equation satisfying the velocity of electron motion is obtained through strict mathematical derivation. This equation effectively describes the complex motion of electrons in a cathode ray tube and aligns closely with experimental observations. The wave image is clear. In contrast, the Schrödinger equation was constructed through a combination of hypotheses and approximations. Although it has achieved great success in non-relativistic quantum mechanics, its treatment of the wave characteristics of microscopic particle motion is superficial, imprecise, and lacks depth. These are two different theories that should not be confused. The theory proposed in this paper cannot replace the Schrödinger equation, nor can the Schrödinger equation replace the theory presented here. In conclusion, the wave equation derived in this paper describes the motion of microscopic particles and belongs to a domain of physics different from the Schrödinger equation. In sum, the Schrödinger equation cannot fundamentally describe the wave characteristics of microscopic particle motion.

It can be seen that the Schrödinger equation does not describe the movement picture of electrons in a cathode ray tube, but merely assumes that microscopic particles only perform simple harmonic motion. Therefore, it is superficial and incomplete! Because of this, self-righteous explanations such as wave-particle duality and probability waves have emerged. The key words of wave-particle duality are wave and particle, and the same is true for this article. Therefore, explanations of physical phenomena such as electron diffraction, the tunneling effect, and Bohr's stationary state hypothesis of hydrogen atoms based on wave-particle duality are expected to be explained by the conclusion of this article as well. This article should be able to complement the Schrödinger equation, and that's all.

Acknowledgments

In the process of writing and submitting this article, we have received the help of Guoshen Zhou, Hong Guo and Shuyue Song. I would like to express my deep gratitude.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Liu, S.S. and Liu, S.D. (2011) Atmospheric Dynamics. 2nd Edition, Peking University Press, 157, 160.

[2] Chen, Y.C. (2024) A Preliminary Study on the Genesis of De Broglie Wave. *Open Access Library Journal*, **11**, 1-7. https://www.scirp.org/journal/paperinformation?paperid=133035

[3] http://k.sina.com.cn/article_6426972733_17f13d23d00100m328.html

[4] Schumm, T., Hofferberth, S., Andersson, L., *et al.* (2005) Matter-Wave Interferometry in a Double Well on an Atom Chip. *Nature Physics*, **1**, 57-62. https://www.nature.com/articles/nphys125