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Information's Relativistic Convey with Matter Wave's Non-Dispersive Propagation

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The Wave-Particle Duality is a basic property of microscopic particles. As a basic concept of quantum mechanics, the wave-particle duality theory from elementary particles to big molecules had been verified by lots of experiments. Different from electromagnetic wave, the matter wave's propagation is not only fast but also adjustable. According to the special relativity theory, the group velocity with which the overall envelope shape of the wave, namely the related particle's propagation and information convey speed is changeable with its energy and related wavelength, among which only the energy exceeds over the minimum value, the propagation can be starting and the velocity is not allowed to surpass the maximum value i.e. the light speed in vacuum. Take electron as an example, if the free electron beam gains energy higher than around 8.187×10^{-14}J and the related wavelength is shorter than around 5.316×10^{-3}nm, the matter wave with information can start to propagate.

Keywords: Matter wave; wave-particle duality; group velocity; non-dispersive propagation; relativistic convey.

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1 INTRODUCTION

Wave-Particle Duality is a basic property of microscopic particles [1]. Inspired by Albert Einstein's light wave-particle duality theory [2]. Louis de Broglie in 1924 proposed that all particles exhibit wave-particle duality. This is referred as matter wave and also called as de Broglie wave [3]. This hypothesis [4] was first confirmed by George Paget Thomson's cathode ray diffraction experiment in 1927 [5] and then The Fullerene molecule in 1999 [6], the Phthalocyanine molecule (consist of 58 atoms) in 2012 [7] and even the big molecule with 25,000 amu in 2019 [8] were discovered in succession with wave-like behaviors.

According to the wave-particle duality theory, de Broglie combined the Einstein mass- energy equation $E=mc^2$ [9] ,one base of the relativity theory related to mass and energy with the Planck relation $E=h\nu$ [10] ,one base of quantum mechanics theory related to wave frequency and energy then equalized both to: $mc^2= h\nu$. However, De Broglie considered that not all matter move with the velocity of light speed in vacuum, so he changed the mass- energy equation from $E=mc^2$ to $E=mv^2$ by replacing c with the actual velocity v and equal both as $mv^2= h\nu$. This important change means that the de Broglie hypothec did not take the relativity theory as its theoretical base and the propagation is non-relativistic [11].

2 THEORETICAL EXPLORATIONS

This article deals with the matter wave's relativistic propagation on bases of the special relativity theory and the Planck relation.

In the matter wave's propagation, the group velocity of a wave is the velocity with which the overall envelope shape of the wave's amplitudes –known as the modulation or envelope of the wave propagates through space and is often thought of as the velocity at which energy or information is conveyed along the wave [12]. The group velocity vg is defined by the equation:

$$vg=\frac{\partial \omega}{\partial \kappa}=\frac{\partial \mathrm{E}}{\partial \mathrm{p}} \tag{1}$$

Where E, p, ω and κ denote total energy, momentum, angular frequency and angular wavenumber. Matter wave's non-dispersive propagation means its propagation in space without effects caused either by interaction with transmitting medium or by geometric boundary condition.

De Broglie concluded that the velocity of a particle should always be equal to the group velocity of the corresponding wave. This conclusion had been proved for free particle's non-relativistic propagation [11] and also now can be proved for free particle's relativistic propagation as below:

According to the special relativity theory, particle's total energy E is

$$E^2= (m_{\circ} c^2)^2+ (pc)^2 \text{ [14]} \tag{2}$$

Where $m_{\circ}$ denotes rest(intrinsic) mass, p is momentum, c is light speed in vacuum. If v denotes particle's propagate speed and γ represents Lorentz factor [15]:

$$\gamma =\frac{1}{\sqrt{1-\frac{V^2}{C^2}}} \tag{3}$$

From formula (1)

$$vg = \frac{\partial \mathrm{E}}{\partial \mathrm{p}} \tag{4}$$

$$=\frac{\partial}{\partial \mathrm{p}}\sqrt{(\mathrm{m}_{\circ}\ \mathrm{c}^2)^2 + (\mathrm{pc})^2}$$

$$= \frac{pc^2}{\mathrm{E}} \tag{5}$$

$$= \frac{\gamma \mathrm{m}_{\circ}\ \mathrm{V}\, c^2}{\gamma \mathrm{m}_{\circ}\ \mathrm{C}^2}$$

$$=v \tag{6}$$

From (4) to (6) de Broglie's conclusion proved.

The matter wave's relativistic propagation can be classified into two types as below:

2.1 Rest Mass m=0

$$E=pc$$

Thus

$$Vg= \frac{\partial \mathrm{E}}{\partial \mathrm{p}} =c \tag{7}$$

This is the group velocity of light, namely the photon's propagation speed in vacuum.

2.2 Rest Mass m≠0

$$E^2 = (m_\circ c^2)^2 + (pc)^2$$

$$Vg = \frac{\partial E}{\partial p}$$

$$= \frac{\partial}{\partial p}\sqrt{(m_\circ c^2)^2 + (pc)^2}$$

$$= \frac{pc^2}{E}$$

And

$$E = \gamma m_\circ c^2 \quad (8)$$

$$P = \gamma m_\circ V \quad (9)$$

$$\gamma^2 = \frac{1}{1-\frac{V^2}{c^2}} = \frac{c^2}{c^2-V^2} = \frac{E^2}{m_\circ{}^2 c^4} \quad (10)$$

Thus

$$V = \sqrt{c^2 - \frac{m_\circ{}^2 c^6}{E^2}} \quad (11)$$

Formula （11） indicates the relation between the particle propagation's velocity, V and the related particle's energy, E in relativistic propagation.

$$As\ c^2 - \frac{m_\circ{}^2 c^6}{E^2} \geq 0$$

So

$$E \geq m_\circ c^2 \quad (12)$$

Let Es to denote the minimum energy needed to start matter wave's propagation

$$Es = m_\circ c^2 \quad (13)$$

And the related wavelength λ, from de Broglie relation [13]:

$$p = h/\lambda \quad (14)$$

$$\lambda = h/p = h/(\gamma m_\circ V) \quad (15)$$

To start the relativistic propagation, a minimum energy Es is needed shown in formula (13).

Take electron as an example, the electron's rest mass, $m_e=9.109\times10^{-31}$kg, the light speed in vacuum, c=299,792,458 $m.s^{-1}$, the Planck constant, $h=6.62607015\times10^{-34}$ J.s. so, the start energy

$$Es = m_\circ c^2$$

$$= 8.187\times10^{-14}\ J$$

Just then, the related start velocity is

$$Vs = \sqrt{c^2 - \frac{m_\circ{}^2 c^6}{Es^2}}$$

$$= 0$$

If the particle with energy, $E=9\times10^{-14}$ J, the propagation velocity will be

$$V = \sqrt{c^2 - \frac{m_\circ{}^2 c^6}{E^2}}$$

$$= 1.245\times10^8\ m.s^{-1}$$

$$= 0.415c$$

According to the de Broglie relation, the related wavelength should be

$$p = h/\lambda \quad (16)$$

$$\lambda = h/(\gamma m_\circ V) \quad (17)$$

$$= 5.316\times10^{-12}\ m = 5.316\times10^{-3}nm$$

In (11), when the energy E tends to infinitely great,

$$E \to \infty$$

the velocity approaches to the light speed c.

$$V \to c$$

3. FACTS AND DATA

The electron microscope uses a beam of accelerated electrons under a very high voltage of several 10^3 to 3×10^6 voltages (the HVEM, i.e. High Voltage Electronic Microscope can be applied up to 200 to 1000 kV) between a cathode, as an electron source and an anode, as an acceleration part, going through a vacuum area to illuminate the specimen and create an image. As the wavelength of electron can be up to 100,000 times shorter than that of visible light photons, electron microscopes have higher resolving power than light microscopes and can reveal the ultrastructure of smaller objects.

If the electron beam is accelerated by anode with voltage of 6×10^2kV, i.e. V=6×10^5 V, and electron's charge, e=$1.602\text{x}10^{-19}$C, electron's mass, m_e=$9.109\text{x}10^{-31}$kg, so the electron's energy accelerated, E_e, group velocity, vg_e, namely the particle's propagation speed v and wavelength, λ_e should equate to:

$$E_e=eV=9.612\text{x}10^{-14}\text{J} \tag{18}$$

$$V=vg_e=\sqrt{c^2-\frac{m_\circ{}^2\ c^6}{E^2}}$$

$$=1.571\times10^8\text{m.s}^{-1}$$

$$\gamma=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$$

$$=1.174 \quad (19)$$

So

$$\lambda_e= h/(\gamma\, m_\circ\ V)$$

$$=3.944\times10^{-12}\text{ m}=3.944\times10^{-3}\text{nm} \tag{20}$$

The minimum energy needed to start propagating is

$$Es=8.187\times10^{-14}\text{J} \tag{21}$$

4 CONCLUTION

The matter wave's relativistic propagation, i.e. the related particle's propagation and information's convey is not only fast but also adjustable. The velocity is changeable with its energy and related wavelength in its non-dispersive propagation, once the energy is over a minimum value and the wavelength is shorter than certain value, the propagation can be starting. Take electron as an example, if the electron's total energy is higher than 8.187×10^{-14}J and the related wavelength is shorter than around 5.316×10^{-3}nm, the matter wave with information can start to propagate.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. French, Anthony: An Introduction to Quantum Physics, W.W. Norton Inc.; 1978.
2. Serway RA. Physics for Scientists and Engineers; 1990.
3. De Broglie, L Nobel. Lecture: The wave nature of the electron. The Nobel Foundation;1929 (2008- 08-30)
4. Feymann R, QED. The Strange Theory of Light and Matter, Penguin; 1990.
5. Thomson GP. Diffraction of Cathode Rays by Thin Film;1927.
6. L'Anmunziata, Michael, Radiactivity: Introduction and history, from the quantum to quarks 2nd, Elsevier Science; 2016.
7. Juffmann, Thomas, Real-time single-molecule imaging of quantum interence Nanotecnology; 2014
8. phys org. Nanotechenology 25 March 2012.
   Retrieved 25 September 2019.
9. Bodanis David: A Biography of the Word's Most Famous Equation; 2009.
10. Schwinger: Planck's energy-frequency relation; 2001.
11. Xinye Wang: Information's super-speed and adjustable convey with matter wave's Non-Dispersive Propagation techRxiv 12789116 14 Aug 2020
12. Leon Nicolas Brillouin: Wave propagation and group velocity, Academic Press Inc New York; 1960.
13. Roger G Newton: A history of physics. Harvard University Press; 2009.
14. Taylor: Classical mechanics. University Science Books. 2004;652.
    ISBN 1-891389-22-X.
15. Yaakov Friedman, Physical Applications of Homogeneous Balls, Progress in Mathematical Physics; 2004.

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