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Sennian Chen
Department of Phys (Retired).
National Hua Qiao University
Fujian, China

Corresponding Author:
Sennian Chen
Department of Phys (Retired).
National Hua Qiao University
Fujian, China

Where do the spin and wave-particle duality of photons and $\pm$ charged elementary particles come from? And what structures these particles possess

Sennian Chen

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Abstract
Until now, we do not know whether elementary particles have structure, but we cannot assert that elementary particles do not have structure, because all experiences tell us that the properties of non-living and living things are closely related to their structure. As their foundation, can the microscopic particles be excluded?
Do photons and charged fermions have structure? What structure? We study the key to the Schrödinger computation that accurately reproduce the energy levels of the Bohr model and the general solution of Schrödinger equation mathematically; we found to satisfy Schrödinger equation the charged fermions must possess a double helix structure of mass density. Such structures plus partial self-rotation make them quantized $\in = h\nu$ and a fixed value spin $+$ or $-\frac{2n+1}{2}\hbar \quad (n=1,2,...)$. We prove that the Maxwell wave equation is simultaneously the Klein-Gordon equation for electromagnetic waves. Then we prove that photons have a double helix structure of EH-energy that makes photons quantized $\in = h\nu$ and a fixed value spin $+\hbar$ or $-\hbar$. There is a charge e in the $\pm$ electron (and $\pm$ charged fermions); a pair of charges $\pm e$ in the photons, they distribute double helically along their side boundaries; these charges produce and carry a circular polarized E-wave and EH-wave respectively. They form two traveling-wave-particle hybrid structures. It is such hybrid structures give them traveling-wave-particle duality. Such dualities can exhibit their wave property and particle property simultaneously in the same experiments. At last, we prove that the electron cloud photo not only exhibits the probability distribution of electrons but also proves the existence of electrons' trajectories around the nucleus; the electrons' motions make the probability distribution. The electron probability distribution around the nucleus is causal. At last we prove that the electron in the main shells (the Eigen states) of a multi-electron atom does not radiate pure EM energy, not fall to the nucleus.

Keywords: Double helices structure, right-handed particle, left-handed particle, inertia vector, mass amplitude, intrinsic self-rotation, travelling wave-particle hybrid structure

Introduction

To answer the question in the title of this paper, our study includes several chapters. Chapter I is the Key to the Schrödinger success in the computation of hydrogen spectral series. Chapter II is the general mathematical solution of the Schrödinger equation for free particles. Chapter III is the necessary conditions for particles to satisfy the Schrödinger equation. Chapter IV The relationship between the double helix structure, quantization $\in = h\nu$ and fixed value spin of electrons ($+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$) and $\pm$ charged fermions $\frac{2n+1}{2}\hbar \quad (n=1,2,...)$. Chapter V is the traveling wave-particle hybrid structure of the $\pm$ charged elementary particles. Chapter VI The proof of the Maxwell wave equation is simultaneously the Klein-Gordon or Schrödinger equation for electromagnetic waves. Chapter VII Photons' double helix EH structure and traveling wave-particle hybrid structure. Chapter VIII The computation to prove that under the principle of charge quantization, double helix structure of E-H plus speed c makes photons quantized $\in = h\nu$ and a fixed-value spin $+\hbar$ or $-\hbar$, no matter whether measured or not.

Chapter IX: By means of the fixed value spin $+\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$ to interpret the Stern-Gerlach experiment. Chapter X The explanation of the Wheeler's single photon double slits delayed choice experiment and single photon double slit interference experiment. Chapter XI: Why the solution in the Schrödinger computation of hydrogen spectral series in 1926 is not an orbit, but the electron cloud? Chapter XII Conclusion
Behind the References is the Appendix, it is for Editor' saving time.

Chapter I Key to the Schrödinger success in the computation of hydrogen spectral series

According to the paper Schrödinger published in 1926, he computed the hydrogen spectral series by treating the hydrogen atom's electron as a $\Psi(x,y,z,t)$ wave moving in a potential well $V(x,y,z)$ created by the proton and suppose it satisfies the partial differential wave equation: [1]

$$\nabla^2\Psi + \frac{2m}{\hbar^2}(E-V)\Psi = 0 \quad \left(V = -\frac{e^2}{4\pi\varepsilon_0 r} \right) \tag{1}$$

Where $V(x,y,z)$ is a potential energy function of the electron in the proton Coulomb electric field.
The computation accurately reproduced the energy levels of the Bohr model. Schrödinger equation details the conduct of $\Psi(x,y,z,t)$ but says nothing about its nature.
What is the nature of the $\Psi(x,y,z,t)$ -wave? Since the Schrödinger equation (1) is a linear partial differential equation, it must satisfy the superposition principle and the electron was treated as a wave, so Max Born supposed that the wave function $\Psi(x,y,z,t)$ represents the superposition state of electrons; and interpreted the $\Psi(x,y,z,t)$ in an abstract configuration space as the probability amplitude, the modulus squared $\Psi^*\Psi(x,y,z,t)$ is equal to the probability density. It distributes around the proton (like a "fog"); the modulus has an important property that $\Psi^*\Psi(x,y,z,t)d\tau$ is the probability that the particle is located in a volume element $d\tau$ at (x,y,z) in space at time t.
This interpretation has brought us a lot of great success, but it also caused some long-standing debates, e.g. the behavior of the wave function collapsing when measured, etc. The behavior of wave function collapse is really weird. [2]
Can we avoid wave function collapse? For this purpose, let us try to find the key to the Schrödinger's success to see if there is another kind of wave the function $\Psi(x,y,z,t)$ may represent.
We have noticed there are some important characteristics in the computation:
(a) Around the proton is a vacuum, so this wave is not the vibration propagation.
(b) Next, the electron is treated as a wave moving in the potential field $V = -\frac{e^2}{4\pi\varepsilon_0 r}$. Because the Schrödinger equation here is a partial differential equation of the de Broglie waves for non-relativistic particles; it originates from $\psi(x,y,z,t) = Ae^{\frac{i}{\hbar}(\in t - \vec{p}\cdot\vec{r})}$. Where $\in = mc^2 = h\nu$, and $p = mV = \frac{h}{\lambda}$ (m is the rest mass here). They satisfy the de Broglie relation. So this wave $\Psi(x,y,z,t)$ must be a traveling wave with electron velocity $\vec{V}$, not with the velocity decided by the uncertainty principle inequality $\geq \frac{\hbar}{2}$. Because the uncertainty principle gives infinite possibilities of velocity to be chosen; electrons move without rules. Under this condition can atoms exist stably? Of course not! Because the movement of electrons in atoms is certainly regular, therefore, the electrons' movement around the nucleus is impossible to be decided by the uncertainty principle.
(c) De Broglie proposed the famous concept of matter waves. His original words in his 1924 doctoral thesis were: We assume that any moving object is accompanied by a wave, and it is impossible to separate the movement of the object from the propagation of the wave. His conjecture was experimentally verified by Davisson and Germer in 1927.
Therefore, the $\Psi(x,y,z,t)$ wave in the Schrödinger computation must be such a traveling wave accompany with the electron; it can precisely adjust its velocity to follow the electron moving and turning around the proton. It is evident that under this condition of "follow the electron moving and turning", the only possibility is that the electron itself forms the $\Psi(x,y,z,t)$ wave. Can a moving body directly form a traveling wave?
(d) As well known, in mathematics the linear motion $z = z - ut$ of a sine curve $x = a\sin z$ will form a traveling sine wave $x = a\sin(z-ut)$; then the periodic distribution of mass (density) expressed by $\sum a_\kappa \sin\kappa z$ or $\sum a_k(\cos kz \pm i\sin kz) = \sum a_k e^{\pm ikz}$ ($a_k = a_k(r)$) (it means a right hand spring or left hand spring or a combination of coaxial springs with different radii) plus linear motion $z = z - ut$ can form a traveling wave directly. In a word, a moving particle itself can form a traveling wave directly, as long as it has a periodic distribution of mass density expressed by $\sum a_\kappa \sin\kappa z$, or by a complex function $\sum a_k e^{\pm ikz}$ along the moving direction. So, the Schrödinger's successful computation proves that the electron has a periodic structure of mass density along the moving direction. But, what periodic structure can make the electron forming a traveling wave that can satisfy the Schrödinger equation? For this purpose, we have to study the general solution of the free particles Schrödinger equation mathematically.

Chapter II The general mathematical solution of the Schrödinger equation for free particles.

Because the Schrödinger equation is a wave equation, in mathematics it has a general solution of the type $f(z-Vt)+f(z+Vt)$. Let us take $\psi(x,y,z,t)\overset{let}{=}\psi_0(x,y,z_0)\psi(z-Vt)=\psi_0(x,y,z_0)\psi(\zeta)$, ($\zeta=z-Vt$) to be an example. Calculate $-\frac{\hbar^2}{2m}\frac{\partial^2\psi(x,y,z,t)}{\partial z^2}$ and $i\hbar\frac{\partial\psi(x,y,z,t)}{\partial t}$, and substitute them into the Schrödinger equations for free particles, Eq. (2) and (3)

$$i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial z}\quad(=E\psi) \tag{2}$$

$$-i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial z}\quad(=E\psi) \tag{3}$$

Then we have the mathematical general solution of the free particle Schrodinger equation as follow: [5]…, [8] or Appendix

$$\psi(x,y,z,t)=\psi_x+i\psi_y=\psi_0(r)\,e^{2\pi i(\frac{z}{\lambda_u}-\nu_u t)}\quad(r=\sqrt{x^2+y^2}\le R,\ \lambda_u\nu_u=u,\ \lambda_u=\frac{h}{mu}=\frac{h}{p_u},\ \nu_u=\frac{mu^2}{2h}=\frac{\in_u}{h}) \tag{4}$$

And

$$\psi(x,y,z,t)=\psi_x-i\psi_y=\psi_0(r)\,e^{-2\pi i(\frac{z}{\lambda_u}-\nu_u t)}\quad(r=\sqrt{x^2+y^2}\le R,\ \lambda_u\nu_u=u,\ \lambda_u=\frac{h}{mu}=\frac{h}{p_u},\ \nu_u=\frac{mu^2}{2h}=\frac{\in_u}{h}) \tag{5}$$

Because the electron and $\pm$ charged elementary particles satisfy the Schrödinger equation, so Eq. (4), (5) are just the free electron and free $\pm$ charged elementary particles wave functions.

Chapter III the necessary condition for the particle to satisfy the Schrödinger equation.

What periodic structure of the particle or particle system, its linear motion can form the wave, Eq. (4) or (5) to satisfy the Schrödinger equation?

Let an unknown function $\psi=\psi(x,y,z)$ represent the inner structure of mass density needed by a particle or a particle system, its uniform motion $z=z-ut$ can form the wave Eq. (4) or Eq. (5) to satisfy the Schrödinger equation. The z on the left side of the equation $z=z-ut$ is a function of t, it represents the uniform motion; the z on the right side is a parameter representing a point z inside the particle. Substitute $z=z-ut$ into the unknown function $\psi=\psi(x,y,z)$, it must satisfy the necessary condition, Eq. (4) or Eq. (5) that is

$$\psi=\psi(x,y,z-ut)\overset{must}{=}\psi_0(r)e^{+2\pi i(\frac{z}{\lambda_u}-\nu_u t)} \tag{6}$$

$$\psi=\psi(x,y,z-ut)\overset{must}{=}\psi_0(r)e^{-2\pi i(\frac{z}{\lambda_u}-\nu_u t)} \tag{7}$$

Let $t=0$, it gives the necessary inner structure for the particle or particle system to satisfy the Schrödinger equation as follow

$$\psi=\psi(x,y,z)\overset{must}{=}\psi_0(r)e^{+2\pi i(\frac{z}{\lambda_u})}=\psi_x\pm i\psi_y \tag{8}$$

$$\psi=\psi(x,y,z)\overset{must}{=}\psi_0(r)e^{-2\pi i(\frac{z}{\lambda_u})}=\psi_x\pm i\psi_y \tag{9}$$

This is the necessary condition for a particle or particle system to satisfy the Schrödinger Equation.

The components of the Eq. (8) (9) are

$$\psi_x=\psi_0(r)\cos 2\pi i(\frac{z}{\lambda_u}) \tag{10}$$

$$\psi_y=\psi_0(r)\sin 2\pi i(\frac{z}{\lambda_u}) \tag{11}$$

Then

$$\tan\theta=\frac{\psi_y}{\psi_x}=\tan 2\pi i(\frac{z}{\lambda_u}) \tag{12}$$

Where θ is nothing to do with the coordinates (x, y). It means that the directions of the vector $\psi(x, y, z)$ at different points (x, y) on the same z -cross section are all the same. So, $\psi(x, y, z)$, Eq. (10) is a plane vector tangent to the particle's cross section at point z. Eq. (10) represents a double helix structure similar to the electric field intensity **E** in the circularly polarized light beam, Fig 1.

Chapter IV The relationship among the double helix structure, quantization $\in= h\nu$ and **fixed value spin of Electrons** ($+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$) **and** $\pm$ **charged fermions** $\frac{2n+1}{2}\hbar \quad (n=1,2,...)$ **.**

(A) Nearly a hundred years of experience tells us that $\pm$ electron, $\pm$ charged elementary particles and atomic nuclei satisfy the Schrödinger equation, so, they should satisfy the necessary condition required by the Schrödinger equation. In other words, any $\pm$ charged elementary particles has a right-handed structure $\psi(x, y, z) = \psi_0(r)e^{2\pi i \frac{mu}{h} z}$ of mass density like a right double-head screw or a left handed structure $\psi(x, y, z) = \psi_0(r)e^{-2\pi i \frac{mu}{h} z}$ of mass density like a left double-head screw.

(B) Because the electrons have an intrinsic spin $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$ and the frequency $\nu_u = \frac{1}{T_u} = \frac{u}{\lambda_u}$ of the microscopic particle can vary with the speed $0 \le u \prec c$; so there must exist a constant and maximum frequency ν that the intrinsic spin corresponds to; It satisfies the condition $\nu_u \le \nu$.

What is the extra frequency? The only possibility is the self rotation around the particle symmetrical axis, an intrinsic self-rotation frequency ν_{self} . It always satisfies the following condition

$$\nu_{self} = \nu - \nu_u \quad (0 \le u \prec c) \tag{13}$$

The total angular velocity vector $\vec{\omega} (= 2\pi \vec{\nu})$ and self-rotation angular velocity vector $\vec{\omega}_{self} \ (= 2\pi \vec{\nu}_{self})$ are all perpendicular to the O-plane, in the same direction as $\vec{u}$ or - $\vec{u}$ depended on whether it is a right-handed or a left-handed particle.

Besides, the concepts of the intrinsic spin and intrinsic self-rotation of the particle are different. Intrinsic spin is for the particle it is treated as a point particle or a particle of no inner structure. As to the intrinsic self-rotation, it is for the particle having a double helix structure. And the intrinsic self-rotation is a real rotation. It always exists, except $U \to c$, $\nu_{elf} \to 0$ to become a "photon".

When a particle is at rest $u = 0$, it gives $\nu_{elf} = \nu$. It means that the magnetic moment of a stationary particle $u = 0$ is totally dependent on its self rotation $\nu_{elf} = \nu$. So, for the static particle, there is an inequality $r \overset{must}{\prec} \frac{c}{2\pi\nu} = \frac{h}{2\pi mc}$ must obey; it is a limitation condition for the radius of the electron (and $\pm$ charged elementary particles); where r is the maximum radius of the $\pm$ charged particles. [8]

Because a particle with intrinsic spin certainly possesses helical structure, so the particles with intrinsic spin certainly have the inner structure as the function Eq. (10) shows; and satisfy the Schrödinger equation.

(C) Let $\nu \overset{let}{=} \frac{\in}{h}$ (h is Plank constant). Because ν is a constant, so $\in$ is also a constant. It has an energy dimension. Compare to the expression of kinetic energy of a non-relativistic particle $\in_u = \frac{mu^2}{2} = h\nu_u$ ($0 \le u \prec c$, $\nu_u \le \nu$) in Eq. (7), (8), the quantity

$$\in= h\nu \ (= mc^2) \tag{14}$$

must be the maximum energy, the total energy ($\in_u$ and $\in_{self}$) of the electron and the particles with an intrinsic spin $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$. Where m is particle's rest mass.

Obviously, the results are also applicable to other $\pm$ charged elementary particles although their intrinsic spin value not all the same.

Under the condition of $\lambda_u \nu_u = u$, if the pitch λ_u of another $\pm$ charged elementary particle is $\frac{1}{2n+1} (n = 1, or 2, or..)$ that of an electron, its frequency ν_u will be $(2n+1) \quad (n = 1, or 2, or..)$ times the frequency that of the electron. It will make the frequency of circular motion on the O-plane $(2n+1)$ times than the electron's frequency. So, these particles intrinsic spin is $\frac{2n+1}{2}\hbar \quad (n=1,2,...)$; they are charged fermions.

(D) Because the electrons and $\pm$ fermions possess their intrinsic spin and helices structure $\psi(x, y, z) = \psi_0(r)e^{2\pi i \frac{mu}{h} z}$ or $\psi(x, y, z) = \psi_0(r)e^{-2\pi i \frac{mu}{h} z}$ ($\frac{mu}{h} = \frac{1}{\lambda_u}$) at the same time; so for these particles, the Eq. (7), (8) must be replaced by the following functions

$$\psi(x,y,z,t)=\psi_x+i\psi_y=\psi_0(r)e^{2\pi i(\frac{z}{\lambda_u}-\nu t)} \quad (\in=h\nu,\ \lambda_u=\frac{h}{p_u}=\frac{h}{mu}) \tag{15}$$

And

$$\psi(x,y,z,t)=\psi_x-i\psi_y=\psi_0(r)e^{-2\pi i(\frac{z}{\lambda_u}-\nu t)} \quad (\in=h\nu,\ \lambda_u=\frac{h}{p_u}=\frac{h}{mu}) \tag{16}$$

This is the equation of motion of the electron and $\pm$ fermions. Their spins are $\frac{2n+1}{2}\hbar \quad (n=0,1,...)$.

The establishment of Eq. (7), (8) shows that the double helix structure of mass density is a major basis to make the electron a fixed-value spin $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$. The double helix structure, quantization $\in=h\nu$ and fixed value spin $+\frac{\hbar}{2}\ or -\frac{\hbar}{2}$ of the electrons are interdependent. The situation of other fermions is similar.

Chapter V traveling wave-particle hybrid structure of the $\pm$ charged fermions

(E) The double helix distributed charge $-e$ or $+e$ along the electron and $\pm$ charged fermions side boundary will produce a double helix external -**E** or +**E** field. This **E**-field becomes a circular polarized travelling $\pm$ **E**-wave when the particle moves with $z=z-ut$. The $\pm$ **E** -wave and the charge $-e$ or $+e$ of the moving particle have the same velocity, frequency, and wavelength. Therefore, the function of $\pm$ **E**-wave and the equation of the charged fermions, Eq. (15), (16) have the same form except the amplitude. To avoid confusion in the following, we use the following function to express the right and left circular polarized **E**-wave respectively.

$$\mathrm{E}(x,y,z,t)=\mathrm{E}_x+i\mathrm{E}_y=\mathrm{E}_0(r)e^{2\pi i(\frac{z}{\lambda_u}-\nu t)} \quad (\in=h\nu,\ p_u=mu=\frac{h}{\lambda_u},\ u\le c) \tag{17}$$

And

$$\mathrm{E}(x,y,z,t)=\mathrm{E}_x-i\mathrm{E}_y=\mathrm{E}_0(r)e^{-2\pi i(\frac{z}{\lambda_u}-\nu t)} \quad (\in=h\nu,\ p_u=mu=\frac{h}{\lambda_u},\ u\le c) \tag{18}$$

The important differences between the equations (15), (16) and equations (17), (18) are that the domain of E -waves is the entire space; and as long as the time extends continuously, the length of the E-wave will extend infinitely $\Delta x\to\infty$. The E –wave exhibits all single states and represents the superposition state.

The second important difference is that although the Eq. (15), (16) is a traveling wave, it is formed by the electron (or charged fermions) double helices structure; it can not split, it is still a particle. So, the waves represented by Eq. (15) (16) also can not split. The $\pm$ charged fermions and the E waves they produce and carry form a traveling wave-particle hybrid structure. It is such a structure that makes $\pm$ charged fermions wave-particle duality. In the following we will show that such a structure allows the electron and charged fermions to exhibit both wave property and particle property simultaneously in the same experiment.

Chapter VI Proof of that the Maxwell wave equation is simultaneously the Klein- Gordon or Schrödinger equation for the electromagnetic wave and photons

Does photon have inner structure? Where do its spin and wave particle duality come from? Because photon speed is $c\succ\succ u$ and above discussion is based on non-relativistic Schrödinger equation, Eq. (2) (3); so, for the photon we have to start from the Klein Gordon equation: [15]

$$\frac{1}{c^2}\frac{\partial^2\psi(x,t)}{\partial t^2}-\nabla^2\psi(x,t)+\frac{m_0^2c^2}{\hbar^2}=0 \tag{19}$$

Because of photons' rest mass $m_0=0$, so for the photon the Klein Gordon equation becomes:

$$\frac{1}{c^2}\frac{\partial^2\psi(x,t)}{\partial t^2}-\nabla^2\psi(x,t)=0 \tag{20}$$

If we let $\psi(x,t)=E(x,t)$, and $\psi(x,t)=B(x,t)$, we get the equations, one for vector **E** and one for vector **B:**

$$\frac{\partial^2 E}{\partial x^2}-\frac{\partial^2 E}{c^2\partial t^2}=0 \tag{21}$$

$$\frac{\partial^2 B}{\partial x^2}-\frac{\partial^2 B}{c^2\partial t^2}=0 \tag{22}$$

For three dimensions they become

$$\vec{\nabla}^2\vec{E}-\frac{\partial^2\vec{E}}{c^2\partial t^2}=0 \quad (23)$$

$$\vec{\nabla}^2\vec{B}-\frac{\partial^2\vec{B}}{c^2\partial t^2}=0 \quad (24)$$

$\vec{E}$ and $\vec{B}$ satisfy the same equation. But that doesn't mean they are equal. $\vec{E}$ and $\vec{B}$ are always perpendicular to each other. And the magnitude of B_0 is smaller than the magnitude of E_0 by a factor of the wave speed c. $B_0=\frac{E_0}{c}$.

Because of $c^2=\frac{1}{\mu_0\varepsilon_0}$, so, equations (23) and (24) are Maxwell's wave equations. Therefore, Maxwell's wave equations are simultaneously the Klein-Gordon or Schrödinger equation for the electromagnetic waves and photons. Therefore Maxwell wave equations can be reasonably used for both the macroscopic phenomena and microscopic photons. The corollaries of Maxwell equations may be available in both the classical and quantum worlds; of course, for the later the research results need the judge by the experiments concerning quantum. Owing to Maxwell's wave equations are simultaneously the Klein-Gordon equation, we can proceed with the following discussions.

Chapter VII the photons' double helix EH structure and traveling wave-particle hybrid structure

Now let us base on Maxwell electromagnetic theory to study the photon. The electric field strength in the far field of a vibrating electric dipole at point O is: [15, 16]

$$E(\rho,\vartheta,\nu,t)=\sqrt{\frac{\mu_0}{\varepsilon_0}}H=\frac{\pi M_0\nu^2}{c^2\varepsilon_0\rho}\sin\vartheta\cos\omega(t-\frac{\rho}{c}) \quad (25)$$

Let us consider an axially symmetrical EM wave beam (abbreviated as s-beam in the following) in the far field. Owing to axial symmetry, the s-beams must be conical and wave surfaces circular. Eq. (1) gives $E=H=0$, when $\vartheta=0$. So, any s-beam from point O has $E=H=0$ at the tangent point if its boundary is tangent to the $\vartheta=0$ line; owing to symmetry, whole side boundary of the s-beam satisfies $E=H=0$. Another s-beam from point O must have $E=H=0$, if it is tangent to the former, and so on then we easily come to a conclusion that any s-beam from point O all have $E=H=0$ at its side boundary. This is the first, also one of the deep influence properties of the s-beams.

Let $\rho=z$ and let (x,y) be the curvilinear coordinate on the s-beam's cross sections. Then the wave function of an s-beam in the far field $z\succ\succ 0$ from point O can be written as

$$E(x,y,z,\nu,t)=A(\frac{r}{R})\frac{\nu^2}{z}\cos 2\pi(\frac{t}{T}-\frac{z}{\lambda}) \quad (r=\sqrt{x^2+y^2}\prec R\prec\infty,\ z\succ\succ 0) \quad (26)$$

Name the geometrical plane perpendicular to the s-beam as observation plane, "O-plane".

Eq. (26) will excite a standing wave on the O-plane at the point $z\ (\succ\succ 0)$:

$$E(r,z,\nu,t)=A(\frac{r}{R})\frac{\nu^2}{z}\cos 2\pi\frac{t}{T} \quad (|r|\prec R\prec\infty),\ t=t'-\frac{z}{c})$$

$$A(\frac{r}{R})_{r=R}=0 \quad \text{(Because of the first important property)} \quad (27)$$

Owing to symmetry, the amplitude $A(\frac{r}{R})$ is an even function. It equals to 0 at $r=\pm R$.

Along any direction tangent to the O-plane, extend the diameter to become an axis and extend the amplitude $A(\frac{r}{R})$ to become an even function along the axis. Then, along any axis the function $A(\frac{r}{R})$ can be expanded into a Fourier series as

$$A(\frac{r}{R})=\sum_{i=1}^{\infty}b_{2i-1}\cos 2\pi(2i-1)\frac{r}{4R}\overset{let}{=}\sum_{i=1}^{\infty}b_{2i-1}\cos 2\pi(2i-1)\frac{r}{\Lambda} \quad (\Lambda=4R,\ |r|\le R) \quad (28)$$

Substitute Eq. (28) into (27), we have

$$E(r,\rho,\nu,t)=\frac{\nu^2}{\rho}\sum_{i=1}^{\infty}b_{2i-1}\cos 2\pi(2i-1)\frac{r}{4R}\cos 2\pi\frac{t}{T}$$

$$=\frac{\nu^2}{2\rho}\sum_{i=1}^{\infty}[b_{2i-1}\cos 2\pi(\frac{r}{\Lambda_{2i-1}}-\frac{t}{T})+b_{2i-1}\cos(\frac{r}{\Lambda_{2i-1}}+\frac{t}{T})]$$

$$\overset{let}{=}E_+(r-\nabla t)+E_-(r+\nabla t) \quad (\Lambda_{2i-1}=\frac{\Lambda}{2i-1},\Lambda=4R,\nabla=\frac{\Lambda}{T},|r|\le R) \tag{29}$$

Here the functions $E_+(r-\nabla t)$ and $E_-(r+\nabla t)$ are two compound waves along opposite radial directions tangent to the O-plane. It leads to the following three results (A), (B), (C). [9] [10] [11]

(A). Symmetry demands all b_{2j-1} and Eq. (28), (29) unrelated of the r-directions. But, because the radiation of a vibrating $\vec{E}$ is anisotropic, so if the beam is linear polarized, the coefficients b_{2i-1} will be different in different r-directions; it conflicts to the symmetry of the amplitude $A(\frac{r}{R})$. So the s-beam must be circular polarized. It makes the average by period of any coefficient b_{2i-1} and the amplitude $A(\frac{r}{R})$ to be rotational symmetry on the O-plane. So, the wave function of an s-beam should be rewritten as

$$E(r,z,\nu,t)=E_x+iE_y=A(\frac{r}{R})\frac{\nu^2}{z}e^{2\pi i(\frac{z}{\lambda}-\nu t)} \quad (A(\frac{r}{R})_{r=R}=0,\ \nu\lambda=c,\ t\succ\succ 0) \tag{30}$$

or

$$E(x,y,z,t)=E_x-iE_y=A(\frac{r}{R})\frac{\nu^2}{z}e^{-2\pi i(\frac{z}{\lambda}-\nu t)} \quad (A(\frac{r}{R})_{r=R}=0,\ \nu\lambda=c,\ t\succ\succ 0) \tag{31}$$

They represent right handed s-beam and left handed s-beam respectively. It is the second important property of the s-beam.

(B). All the compound traveling waves $E_+(r-\nabla t)$ and $E_-(r+\nabla t)$ are tangent the O-plane and radial, therefore the energy flow through any cross-section in a sector is the same. It means:

$$S_+(r_j,\rho,t)\,r_j\,\delta\theta\,\delta\rho=S_+(r_k,\rho,t)\,r_k\,\delta\theta\,\delta\rho \quad (0\prec r_j\prec r_\kappa\prec R) \tag{32}$$

Here the Poynting Vectors are $S_-=S_+=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_+^2=\sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{A^2(\frac{r}{R})}{\rho^2}\nu^4\sin^2\theta$. Let $r_j\to r$, $r_\kappa\to R$ in Eq. (32) and let $A_R=\lim_{r\to R}A(\frac{r}{R})=A(1)$ be the limit at $r\to R$; then we have the third important property of the s-beam:

$$A(\frac{r}{R})=A_R\sqrt{\frac{R}{r}} \quad (0\prec|r|\prec R,\ A_R=\lim_{r\to R}A(\frac{r}{R})=A(1).\ \text{But}\ A(\frac{r}{R})_{r=R}=0) \tag{33}$$

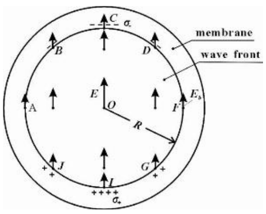

Fig. 1 Sketch map of the symmetrical distribution of the field E, $A(\frac{r}{R})=A_R\sqrt{\frac{R}{r}}$ on the wave surfaces and the charge density σ_θ on the inner side of the membrane.

(C). When $r\to\pm R$, the limits of $E_+(r-\nabla t)$ and $E_-(r+\nabla t)$ all equal to $A_R\ (\ne 0)$. But because of all the $\left|\cos 2\pi(2j-1)(\pm\frac{r}{4R})\right|_{r=\pm R}=0$ $(j=1,2,...)$, then according to Eq. (29) we have

$$\left|E_+(r-\nabla t)+E_-(r+\nabla t)\right|_{r=\pm R}\equiv 0 \quad (r=\pm R) \tag{34}$$

This relation proves that the whole side boundary is a surface of perfect reflection; the wave $E_+(r-\nabla t)$ (and $E_-(r+\nabla t)$) will be reflected back at the side boundary with 180 ^{0} phase loss and become $E_-(r+\nabla t)$ (and $E_+(r-\nabla t)$). Because the reflection can not

happen between the vacuum and field; logically speaking the only possibility is there must have a membrane (its rest mass=0) around lateral conical surface accompany from the source to make the reflection, although we now temporally don't know what is the material. This is a key importance property, the forth important property of the s-beam.
The existence of the side membrane leads to the following nine results (C_1)… (C_9).

(C_1) The momentum rate of change

$\frac{2S(R,\rho,\theta)}{c}$ perpendicular to the side membrane on any wave surface will course a pair of circular tension $T(R,\rho,\theta)$ along the membrane

$$T(R,\rho,\theta) = \frac{2S(R,\rho,\theta)}{c}R = \frac{2\Phi^2}{cR}\sqrt{\frac{\varepsilon_0}{\mu_0}}A_R^2\,\nu^4\sin^2\theta \tag{35}$$

Tension $T(R,\rho,\theta)$ distributes double helically along the side boundary; its maximum $T_{\max}(R,\rho,\theta)$ passes through the points A and F, Fig.1. This is the fifth important property of the s-beam.
(C_2) The electric field intensity **E** in the cross sections that sticks tightly to the membrane will induce a pair of $\mp$ charge density σ on the inner side of the membrane: $\sigma_\theta = D_n = \varepsilon_0 E_n$ and because of the $E_n = \frac{A_R}{z}\nu^2\cos\theta$, Fig. 1. The absolute value of σ_θ is

$$\sigma_\theta = \left|\varepsilon_0\frac{A_R}{z}\nu^2\cos\theta\right| \quad (0 \le \theta \le \pi) \tag{36}$$

In the mean time, outer surfaces of the membrane will induce a pair of $\pm$ charge density σ_θ.
The points of the same σ_θ (+ and -) on all outer wave surfaces form an equal σ_θ -double helix. It is the sixth important property of the s-beam. (C_3) So, on the outer side of the s-beams' membrane there is a pair of helical distributed $\pm$ charges q:

$$q = \int_z^{z+\delta}dz\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\sigma_\theta R\,d\theta = 2\varepsilon_0\Phi A_R\nu^2\delta \quad \left(\Phi = \frac{R}{z}\right) \tag{37}$$

Where δ indicates the charged length along the membrane. According to the principle of charge quantization, $q = \pm e$ is the lowest energy s-beam that can exist in reality. The others are $\pm ke\ (k = 2,3,\ldots)$, e.g. laser, etc. We name the s-beam with $q = \pm e$ as an elementary train. An elementary train possesses $\pm$ charge e, relative lowest energy ϵ and shortest train length δ. It is the seventh important property of the elementary train.
(C_4) When the elementary train moves forward, the membrane perimeter will become longer and longer. A maximum radius $R_{\max}$ of the membrane must exist, otherwise the train will be broken at last, no meaningful information from far can reach us. It contradicts our experiences.
When an elementary train is just emitted, its energy distributes all over the conical train. After the radius grows up to the maximum $R_{\max}$ since $z = z_0$, its energy ϵ begins to be restricted in a cylindrical lateral membrane of radius $R_{\max}$, let us named it as ϵ-(energy) packet. So, the length of the ϵ-packet is δ. It is the eighth important property of the elementary train.
For the ϵ- packet, Eq. (30), (31) become

$$E(r,z,\nu,t) = E_x + iE_y = A\left(\frac{r}{R_{\max}}\right)\frac{\nu^2}{z_0}e^{2\pi i\left(\frac{z-z_0}{\lambda}-\nu t\right)} \quad (\nu\lambda = c,\ z \succ z_0 \succ\succ 0) \tag{38}$$

and

$$E(r,z,t) = E_x - iE_y = A\left(\frac{r}{R_{\max}}\right)\frac{\nu^2}{z_0}e^{-2\pi i\left(\frac{z-z_0}{\lambda}-\nu t\right)} \quad (\nu\lambda = c,\ z \succ z_0 \succ\succ 0) \tag{39}$$

Inequality $z_0 \succ\succ 0$ indicates that the s-beams are in the far field. According to Eq. (9), the amplitude of the ϵ- packet is

$$A\left(\frac{r}{R_{\max}}\right) = A_R\sqrt{\frac{R_{\max}}{r}} \quad \left(0 \prec |r| \prec R,\ A_R = \lim_{r\to R}A\left(\frac{r}{R_{\max}}\right) = A(1).\ \text{But}\ A\left(\frac{r}{R_{\max}}\right)_{r=R} = 0\right) \tag{40}$$

Where $A_R = \lim_{r\to R_{\max}}A\left(\frac{r}{R_{\max}}\right) = A\left(\frac{r}{R_{\max}}\to 1\right)$ is a constant; and $A\left(\frac{r}{R_{\max}}\right)_{r=R} = 0$ is because of the property I.

The equilibrium between the helical distributed charges $\mp e$, the stresses $T(R,z,\theta)=\Sigma\delta R$ along the membrane and the circular polarized EM field inside, they construct a very steady structure to keep integrity. It can keep and bring the information from deep universe to us.

In the mean time, the membrane is also an EM shielding it can avoid the ordinary external EM influences during propagation.

(C_5) On the outer surface of the $\in$- packet's cylindrical side membrane there is a pair of double helix distributed $\pm$ charge e; it produces and carries a double helix external electric E-field and move together. Because it has a light velocity c, so owing to the electromagnetic induction this E-field becomes a circular polarized EH wave (light wave) accompany by the $\in$- packet; we name this wave as ψ -wave. The ψ -wave has the same frequency and wavelength as the $\in$- packet, except the amplitude, so the ψ - wave function is

$$E_\psi(r,z,\nu,t)=E_x+iE_y=A(r)\frac{\nu^2}{z_0}e^{2\pi i(\frac{z-z_0}{\lambda}-\nu t)} \quad (z\succ z_0\succ\succ 0,\ r\prec\infty,\ \nu\lambda=c) \tag{41}$$

and

$$E_\psi(x,y,z,t)=E_x-iE_y=A(r)\frac{\nu^2}{z_0}e^{-2\pi i(\frac{z-z_0}{\lambda}-\nu t)} \quad (z\succ z_0\succ\succ 0,\ r\prec\infty,\ \nu\lambda=c) \tag{42}$$

The elementary train is consisted of an $\in$- (energy) packet and a ψ - wave. They form a travelling wave-particle hybrid structure. This is the ninth important property of the elementary train.

We will exhibit in the following that it is the combination of the $\in$- packet and ψ - wave that makes the elementary train traveling wave-particle duality. Wave functions (41) and (42) completely describe the quantum states of the $\in$- packet (photon) in the experiments. It is the $\in$- packet's probability wave. Especially, we will show in the following that such a hybrid structure can act as both a traveling wave and a particle simultaneously in the same experiments.

We have noticed that because of this hybrid structure, the ψ - wave only possesses wave property; and the $\in$- (energy) packet is an energy quantum and carries a charge quantum e, it is indivisible, so the $\in$- packet only possesses particle property. Neither $\in$- packet nor ψ -wave has the duality in traditional sense.

Chapter VIII The computation to prove that under the principle of charge quantization, the double helix structure of E-H plus speed c makes photons quantized $\in=h\nu$ and a fixed-value spin $+\hbar$ or $-\hbar$, no matter whether measured or not.

(C_6) The ring area on the elementary train's cross section is $d\sigma_r=2\pi z^2\sin\varphi\, d\varphi\approx 2\pi r\, dr$ and then the average **E-H** energy in the $\in$- packet is

$$\in=\frac{1}{2}\int_{z_0-\delta}^{z_0}dz\int_{r=0}^{R}\varepsilon_0\frac{A^2(\frac{r}{R_{\max}})}{z^2}\nu^4 2\pi r\,dr \tag{43}$$

Where δ is the length of the $\in$-packet. Because of Eq. (33), we have:

$$\in\overset{(33)}{=}\frac{1}{2}\int_{z_0-\delta}^{z_0}dz\int_{\phi=0}^{\Phi}2\pi\varepsilon_0 A_R^2\Phi\nu^4\,d\phi=\pi\varepsilon_0A_R^2\Phi^2\nu^4\delta \quad (\Phi=\frac{R}{z}=\frac{R_{\max}}{z_0}) \tag{44}$$

Where z_0 is the distance between the point source O and the end of the elementary train when the train just becomes totally cylindrically.

On the other hand, after the $\in$-packet becomes totally cylindrical its energy is

$$\in=\frac{1}{2}\int_{z_0}^{z_0+\delta}dz\int_{r=0}^{R_{\max}}\varepsilon_0 A_R^2R_{\max}\nu^4\,2\pi\,dr=\pi\varepsilon_0A_R^2R_{\max}^2\nu^4\delta \tag{45}$$

Because of the energy conservation, Eq. (44) and (45) must equal, it leads to $z_0=1m$ for any ν. Any elementary train of different frequencies needs the same time:

$$t_0=\frac{z_0}{c}=\frac{1}{c}\sec \tag{46}$$

to become cylindrical. This is the tenth important property of the elementary train.

(C_7) Let $q=e$ and eliminate the variable δ from Eq. (37) and (45), we have

$$\in=h\nu \tag{47}$$

Where

$$h = \frac{\sqrt{3}}{4} ce A_R \quad (48)$$

Because the limit value A_R is a constant, so h is also a constant independent to the frequency ν. Compare to the Einstein's relation $\in = h\nu$, the constant h here is just the Planck constant. The $\in$-packet possesses energy $\in = h\nu$. It is the eleventh important property of the elementary train.

Einstein's relation $\in = h\nu$ can be derived directly from the Maxwell EM theory itself under the principle of charge quantization.

(C_8) The physical mechanism which can make the translational motion of the $\in$-packet a fixed-value spin $+\hbar$ or $-\hbar$ no matter whether measured or not.

It is easy to see that when the circularly polarized $\in$-packet passes vertically through the O- -plane, observers will find very many circular trajectories with different radius on any O-plane. Each circular trajectory is composed of different mass elements dm from the same helix of an $\in$-packet. In other words, translation motion makes the mass $\sum dm$ rotated on the O-planes to form angular velocity and angular momentum. Its electromagnetic energy becomes the sum of equivalent mass elements of different radii, which form a circular motion on the O plane. The translational motion of the circularly polarized light excites a circular motion on the O-planes. This is a special kind of the rotation different from the axial self-rotation.; it is such a mechanism that makes the angular momentum of the circularly polarized light; it is also the spin mechanism of the photon.

In fact, for simplify we let $z_0 = n\lambda$, $z = z_0 + \wedge = n\lambda + \wedge$, $(0 \le \wedge \le \delta)$ and substituting it into Eq.(41)(42), the $\in$-packet will excite a group of circular motions of different radius $r\,(\le R_{\max})$ and initial phases $\frac{\wedge}{\lambda}$ within the region $(0 \le \wedge \le \delta)$ in the space connected to the z_0 O-plane:

$$E(r, z \ge z_0, t) = A(\frac{r}{R_{\max}})\frac{\nu^2}{z_0} e^{2\pi i(\frac{\wedge}{\lambda} - \nu t)} \quad \text{(Inside the region } 0 \le \wedge \le \delta\text{)} \quad (49)$$

Or

$$E(r, z \ge z_0, t) = A(\frac{r}{R_{\max}})\frac{\nu^2}{z_0} e^{-2\pi i(\frac{\wedge}{\lambda} - \nu t)} \quad \text{(Inside the region } 0 \le \wedge \le \delta\text{)} \quad (50)$$

Where ν is the rotation frequency of the circular motion, and $(0 \le \wedge \le \delta)$ is the $\in$-packet's length region on the space connecting to the O-plane.

Because of the $\in = mc^2$, $dm = \frac{d\in}{c^2}$ and refer to the Eq. (45), the $\in$-packet's moment of inertia I about the symmetrical axis perpendicular to the O-planes is

$$I = \frac{1}{2}\int_{z_0}^{z_0+\delta} dz \int_{r=0}^{R_{\max}} r^2 (\frac{1}{c^2}\varepsilon_0 A_R^2 R_{\max} \nu^4 2\pi\, dr) = \pi \varepsilon_0 A_R^2 R_{\max}^4 \nu^4 \frac{\delta}{3c^2} \quad (51)$$

According to the definition of spin (angular momentum), the spin Σ of the elementary train is $\Sigma = 2\pi\nu I$.

On the other hand, during a beam of circular polarized light is incident on an absorbing surface, classical EM theory predicts that the surface must experience a torque. The torque T per unit area is: [3, 4]

$$\mathrm{T} = \frac{\mathrm{I}}{2\pi\nu} \quad (52)$$

Irradiance I of the beam is the power per unit area. Owing to the elementary train energy is quantized as we proved in the above; it is composed of N elementary trains. N Is the number of the trains per unit area that hit the surface per second. Then the total energy absorbed per unit area is $\mathrm{I} = N\in$. And the torque per unit area is $\mathrm{T} = N\Sigma$, so we have the spin of the elementary train:

$$\Sigma = \frac{\in}{2\pi\nu} \quad (53)$$

Substitute the Eq. (47) $\in = h\nu$ into (53), we have the spin of the elementary train:

$$\Sigma = \frac{h}{2\pi} = \hbar \qquad (54)$$

This is a fixed value spin unrelated to whether it is measured or not. [12]
Because the $\in$-packet's helical structure has two directions, clockwise and counter clockwise, so its rotation directions on the O-planes have two directions, clockwise or counter clockwise. Therefore an elementary train has a fixed value spin $+\hbar$ or $-\hbar$. This is the twelfth important property of the elementary train (photon).
All in all, so many properties of the elementary trains are as same as the photon's; we of course can treat the elementary train as a photon and vice versa.

Next, let $q=e$ and eliminate δ from Eq. (37) (51), then according to $\Sigma = 2\pi\nu I$ and Eq. (47),(54) we have

$$R_{\max} = \frac{\sqrt{3}c}{2\pi\nu} \quad (\overset{c=\lambda\nu}{=} \frac{\sqrt{3}}{2\pi}\lambda) \qquad (55)$$

Let $q=e$ and eliminate A_R^2 from Eq. (37) (51), then, we have the length of the $\in$-packet (photon):

$$\delta = \frac{\pi e^2}{4\varepsilon_0 h\nu} \qquad (56)$$

Then

$$\frac{\delta}{R_{\max}} = \frac{\sqrt{3}\pi^2 e^2}{6c\varepsilon_0 h} \approx 0.04 \qquad (57)$$

The shape of the $\in$-packet (photon) is like a coin. If we take the green light $\lambda = 6\times10^{-7}m$ as an example, the green light photon's $R_{\max}$ is about $1.7\times10^{-7}m$. Its length is about $L \approx 6.6\times10^{-9}\,m$.

The size $\pi R_{\max}^2$ of cross-section is matter for collision probability; the length δ seems not important.
(C_9) When an $\pm$ electron collides with a $\mp$ positron, the result of the low energies collision is the production of two high-energy photons: Because any photon here has been proved having a fixed value spin $+\hbar$ or $-\hbar$ no matter measured or not. Therefore, the quantum state of any photon in the pair production can be described independently of the others. So the entanglement of two photons in the pair production does not seem to exist.
These two photons do have a clockwise and counter clockwise stable relation just like a pair of gloves; right-handed part is always right–handed; left-handed is always left-handed, no matter how far they separate. To test these conclusions that these photons have fixed value spin or they are in the entanglement state which one is right, it is evident if we split a pair of left-handed and right-handed photons into two beams, X_1 and X_2; and we always observe the same beam X_1 or X_2 to see whether the spin direction of this photon always keep unchanged or vary randomly, then we can judge that the spin direction $\pm$ of the photon is decided by the double helix structure or decided by the collapse from its " entanglement state"; because for quantum entanglement, the quantum state of a beam is not definite.

Chapter IX: By means of the fixed value spin $+\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$ to interpret the Stern-Gerlach experiment.
(F) In 1925 owing to there was no classical analog to spin at that time, Uhlenbeck and Goudsmit postulated the existence of a new intrinsic property of elementary particles that behaved like an angular momentum as a means to explain the Stern-Gerlach experiment. Later, this intrinsic property was termed as spin by Pauli. Spin is treated as an intrinsic form of angular momentum.
Since then, we always treat that the state of an electron spin (include the $\pm$ charged atomic and subatomic particles and photons) is not defined, electron is in the superposition of two states, $+\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$; and collapses into one of them when measured (in Stern-Gerlach experiment, it means when they passing through the magnetic field). Later, the concept of quantum entanglement was developed.
However, now we know there is another possibility that the spin of the electron is mainly because of the electron's double helix structure of mass density; such a structure is a corollary of the Schrödinger successful computation of the hydrogen spectral series. It seems it is better one. Of course the decisive criteria is which one can be confirmed by the experiments.
To distinguish if the fix spin mechanism is available, let us discuss the Stern-Gerlach experiment:
Fig. 2 is a sketch map of the Stern-Gerlach experiment. The direction of magnet B is (upward) along the z-axis. The slit is perpendicular to the paper. An inhomogeneous magnetic field, it bends the front part of the upward magnetic field B forward; and the rear part backward (along the -y direction). A beam of silver atom injects along the y-axis (the O-planes of electrons in the atom are also perpendicular to the y-axis). After the superposition state collapse to single state, the magnetic moment μ of the electron in the silver atom is proportional to its angular momentum (spin) and has the same direction of $\mu \propto spin = +\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$. So the beam split into two beams, right-handed and left-handed beams.

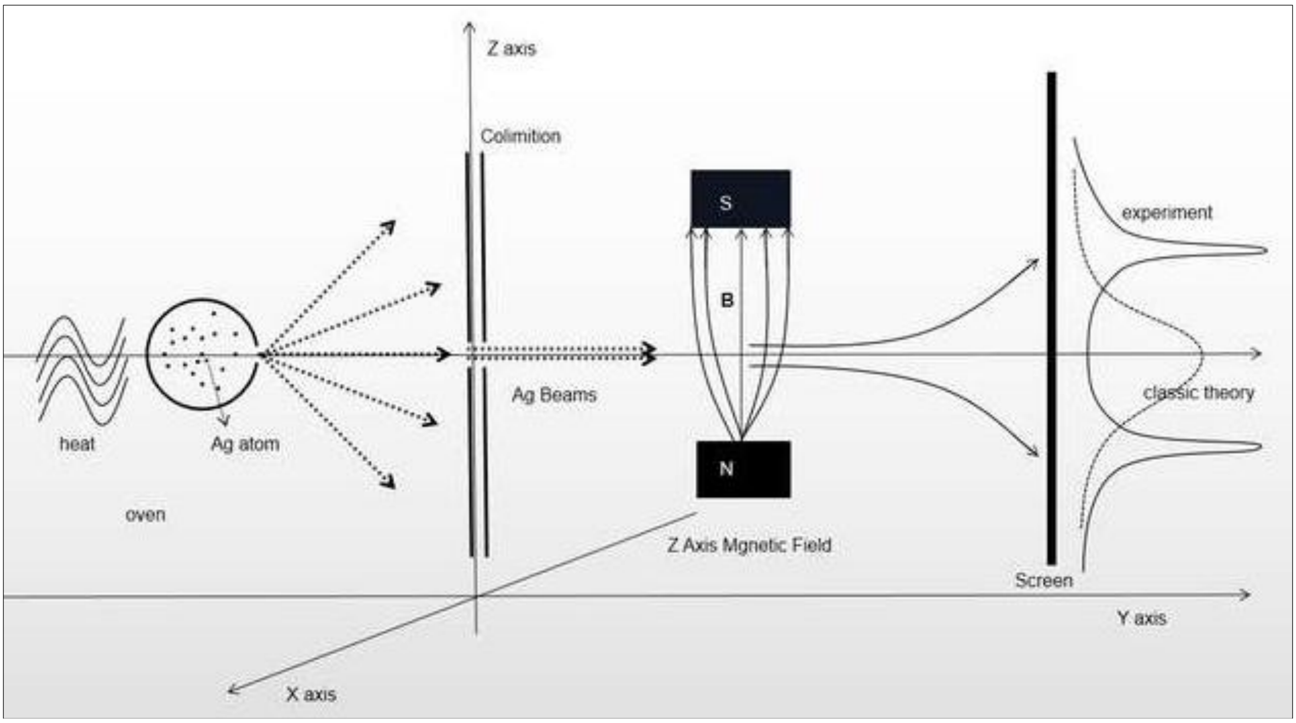

Fig 2: Sketch map of Stern-Gerlach experiment

If electrons have a fixed value spin $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$ the explanation is different. Let us take z-axis as a reference the electron with right-handed spin $E_+ = E_0 e^{i(\omega t+\alpha)}$ can be decomposed as two components:

$$E_z = E_0 \cos(\omega t+\alpha) \text{ And } E_x = E_0 \sin(\omega t+\alpha) \quad (58)$$

And the electron with left-handed spin $E_- = E_0 e^{-i(\omega t+\beta)}$ can be decomposed as the two:

$$E_z = E_0 \cos(\omega t+\beta) \text{ And } E_x = -E_0 \sin(\omega t+\beta) \quad (59)$$

Because to forming light spots on the screen and photo that we can see it needs a lot of silver atoms, so the number of silver atoms must be $E_0 \succ\succ 1$.

Because the Lorentz force acts at the electron is $\vec{F} = -e\vec{V}\times\vec{B}$, so the z-component $E_z = E_0 \cos(\omega t+\alpha)$ has no contribution to the deflection of the silver atom toward the z-direction; only the x- components $E_x = E_0 \sin(\omega t+\alpha)$ and $E_x = -E_0 \sin(\omega t+\beta)$ can make the $\pm$ z-deflections. But, any of these x- components have two directions +x and –x in a period. So the direction of deflection is mainly decided by the initial phase α (and β) of the electron. If the charge e moving direction on the O-plane made by the initial phase α is toward +x when it enter the rear part of the inhomogeneous magnet, the Lorentz force $-ev\times B$ that acts at the electron will make the beam upward; otherwise, if it's moving direction is toward -x, the force will make the beam downward. Because the initial phase α and β are independent, when the α makes the beam of right-handed spin upward, the beam of left-handed spin need not upward simultaneously. So, the upward beams are almost all right-handed. Owing to the same reasons the downward beams are almost all left-handed. This conclusion is as same as the explanation by means of the mechanism of superposition state.
Now let us discuss the sequential experiments of the multi-level Stern-Galach experiment; the results of two mechanisms are different.

(a) If the direction of the magnetic field in the second instrument is the same as that in the previous since the initial phase α of electrons in the right-handed beam do not changed in the propagation, so the direction of deflection is the same as that in the previous instrument. In other words, after the second deflection, the right-handed beam is still a right-handed beam; and the left-handed beam is still a left-handed beam. The results from two mechanisms are the same.
(b) If the direction of the magnetic field **B** in the second instrument is changed to the x direction.

Since the beam is no longer in a superposition state but in a single state; it is difficult to explain why its output can split into two beams. For the mechanism of this paper, let us take x direction as reference the right-handed

spin $E_+ = E_0 e^{i(\omega t+\alpha)}$ can be decomposed as

$E_z = E_0 \cos(\omega t + \alpha)$, $E_x = E_0 \sin(\omega t + \alpha)$ (60)

The x-vibration has no contribution to the x-deflection; only z-vibration can make the z-deflection up or down. So we can delete $E_x = E_0 \sin(\omega t + \alpha)$ from Eq. (60), and added + $\frac{1}{2} E_x = \frac{1}{2} E_0 \sin(\omega t + \alpha)$ and $-\frac{1}{2} E_x = -\frac{1}{2} E_0 \sin(\omega t + \alpha)$ into Eq. (60); then, we have

$$E_z = E_0 \cos(\omega t + \alpha) + \frac{1}{2} E_0 \sin(\omega t + \alpha) - \frac{1}{2} E_0 \sin(\omega t + \alpha) = \frac{1}{2} E_0 e^{i(\omega t + \alpha)} + \frac{1}{2} E_0 e^{-i(\omega t + \alpha)} \quad (61)$$

So for the new instrument where **B** is along x direction, the right-handed spin $E_+ = E_0 e^{i(\omega t + \alpha)}$ can become the sum of two beams with right-handed and left-handed spins respectively. And after the magnet B, they split into upward beam and downward beam. Because of $E_0 \succ\succ 1$, and $\frac{1}{2} E_0 \succ\succ 1$,; they form two sports on the screen or photo as the experiments show.

It is easy to see for the silver atom beam with left-handed electron spin the result is the same; it splits into two beams upward and downward.

(G) For the electron and $\pm$ charged elementary particles and $\pm$ atomic nucleus ($-$ here mean antiparticles), any one of them possesses a charge $-e$ or $+e$, but two directions of mass density and charge helices. So they all fall into two categories: anyone possesses a charge $-e$ (or $+e$) but different directions of mass density and charge helix, like right-handed positrons and left-handed positrons; right-handed electrons and left-handed electrons, etc.

Because they have a double helix structure of inertia vectors $\psi(x, y, z) = \psi_0(r) e^{\pm 2\pi i \frac{mu}{h} z}$ and a charge $-e$ (or $+e$) at the same time, the repulsion force between the same sign of charge will split the charge element de ($\sum de = e$) into $2 \times \frac{de}{2}$ and symmetrically locate at two ends of the diameter on every cross-section. Due to the helical distribution of the cross sections, the charge $-e$ (and $+e$) is indeed a pair of charged double helix on the side boundary of the charged particles.

Right-handed and left-handed charged moving particles produce different orientations of magnetic flux density B perpendicular to the O-plane; two categories of these charged particles are distinguishable through the magnetic B; they satisfy F-D statistics. As for the photons, according to the papers, [5, 11] the far field of the vectors E and B from a pair of $\pm e$ on the side boundary of the photon will offset each other, they are indistinguishable and obey B-E statistics.

(H) We can imagine when the temperature of the metal wire is getting lower and lower until the kinetic energy of the electrons cannot overcome the magnetic interaction between the electrons; then, the electrons of the same category and the electrons of different category but having the same direction of magnetic flux density B will one by one string up along the electric circuit and form an independent circular electric current at last. Under this circumstance no collision will happen between the electrons current and the nuclei, the current will become almost of no resistance $R \cong 0$ (superconducting state).

(J) Can the Schrödinger equation describe the free motion of macroscopic objects? For the macroscopic object, the axially symmetrical directions of all atomic nuclei inside at room temperature are isotropic, not in the same direction. So a uniformly moving macroscopic object can not satisfy the necessary condition, and can not satisfy the Schrödinger equations

But when the temperature becomes low enough, there exists a possibility that the electrons of the same category and the electrons of different category but having the same direction of magnetic flux density B, the symmetrical axis of all these electrons may gradually approach to the same direction and satisfy the necessary condition for the Schrödinger equation. Then, they can satisfy the equation under the low enough temperature and become superconductive.

Chapter X The explanation of the Wheeler's single photon double slits delayed choice experiment and single photon double slit interference experiment.

(L) How does the travelling wave-particle hybrid structure explain the Wheeler's single photon double slits delayed choice experiment? He designed this experiment to show that the conventional theory will lead to a strange inference: "The present behavior of the observer can determine what happened in the past".

Can the travelling wave-particle hybrid structure avoid such a strange inference?

$\pm$ Charged elementary particles and photons they all have a travelling wave-particle hybrid structure. Let us take the photon as an example. [3, 7]

Because the fundamental feature of a quantum is indivisible, so when a single photon is emitted from a light source and arrives at the first half-silvered mirror BS_1, the $\in$-packet as an energy quantum cannot split into two parts; the only possibility is that the first come ψ -wave splits into two beams to transmit I_1 and reflect I_2 respectively. When they reach two photon detectors D_1 and D_2, because only one beam of them carries an $\in$-packets and the photon detector D can not detect the wave, so only one detector has a reaction. It can determine which path the photon takes (D_1or D_2).

If we suddenly put the second half-silvered mirror BS_2 in front of the two detectors, it can make the wave beam with an $\in$-packets and the second wave beam with no $\in$-packets to interfere in the mirror BS_2 (the interfere happens between two ψ -wave beams, not the $\in$-packet).

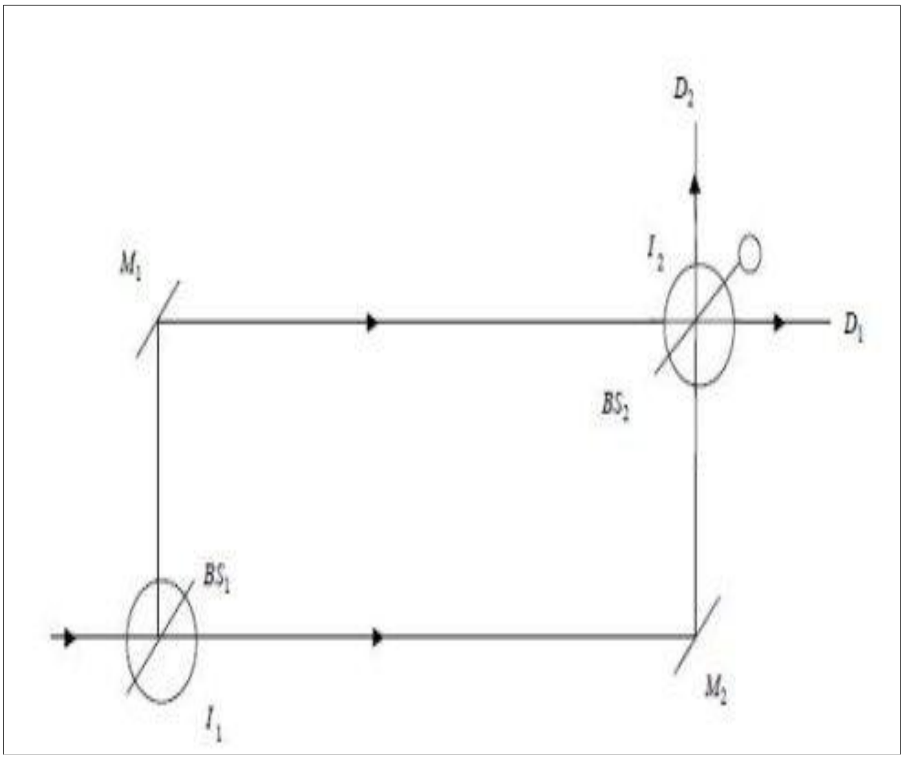

Fig 3: Wheeler's single photon double slits delayed choice experiment, wiki.

If the optical path difference is properly adjusted, the interference wave beams can be canceled in one direction (D_1or D_2), the detector in this direction will not be able to be brightening no matter whether a photon or no photon reaches there. The situation of having a photon arriving, but dark is like the photon arrives at the dark fringe in the interference pattern, it becomes dark. And the detector in the other direction will be definitely brightening as long as it receives a photon. So, owing to the travelling wave-particle hybrid structure, the strange inference: "The present behavior of the observer can determine what happened in the past" doesn't appear. [10] [11]

(M) Single particle double slit interference experiment and quantum tunneling effect.

In the single particle double slit experiment, because the $\in$-packet cannot split into two parts, so the only possibility is that the first come ψ -wave splits into two beams to pass the slits and form a phase differences, an interference pattern on the screen. [13, 14] This interference pattern exhibits the electron's superposition state. The Schrödinger equation does satisfy the superposition principle.

As for the $\in$-packets, from the principle of light diffraction and particle point of view, every one of the $\in$-packets will suffer a momentum Δp_x at the slit Δx and based on probability to locate randomly at a point on the screen. The light spot on the screen is one-to-one correspondent to the $\in$-packet radiated from the single photon light source. No evidence from the spot has ever shown that the $\in$-packet has been split. So, one by one light spot on the screen exhibits the particle property of the photon radiates from the single photon source, no matter which slit they pass through. When the time passes by, the fringe of light sports gradually develops; the light spots on the screen will form an interference patterns at last. In a word, interference fringes are formed by the random accumulation of particles on the screen according to the superposition state formed by the particles' ψ -wave, rather than by the self-interference of particles. This experiment exhibits both wave property and particle property of photons simultaneously in the same experiment. Obviously, similar experiments for the $\pm$electrons and $\pm$charged fermions will have the same explanation, because they also have the traveling wave-particle hybrid structures.

The travelling wave-particle hybrid structure is also available to explain the quantum tunneling effect. It is the ψ -wave that splits out two beams to reflect and to penetrate the high barrier respectively; as for the particle itself, it randomly penetrates the barrier with a very small probability as the calculation base on the Schrödinger equation shows.

Therefore, the traveling ψ -wave of photons and the traveling **E**-waves of $\pm$electrons and $\pm$charged fermions are just their probability waves. Their probability waves are produced by themselves respectively.

All in all, in these typical experiments, the **E**-waves and ψ -wave play the roles of superposition state for the charged fermions and photons to choose.

If one beam of the $\in$-packets is detected (being absorbed or disturbed) by a detector, the ψ -wave beam it carries must also disappear or disturbed, because the ψ -wave is produced and carried by the $\in$-packets; they exist or disappear or disturbed at the same time. The remaining part will become a single slit diffraction, if exposure time is long enough.

If one of the ψ –wave beams in the experiment is disturbed to disable by certain reasons, only another beam of the ψ –wave with its particle can reach the screen, then the total particles that one by one passes through the same slit Δx will be deflected symmetrically. As long as the experiment time is long enough, it will not only form a symmetrical pattern on the screen, but a single-slit diffraction pattern.

Chapter XI. Why the solution of the Schrödinger computation for hydrogen spectral series in 1926 was an electron cloud rather than an orbit? How are the cloud formed?

The electron cloud is the solution of the Schrödinger equation. It exhibits the probability distribution of electrons around the nucleus. The electron cloud photo is a proof of that the electron cloud around the nucleus is really exist; the Schrödinger's computation is right. The problem is now how are the cloud form? It is probabilistic or causal?

First of all, the electrons cloud is impossible to be the probability distribution if the electron is static in the cloud, because a static electron would fall into the nucleus due to electrical attraction, which contradicts the experimental facts. So, the probabilistic distribution must be a result of the electron's mechanical motion around the nucleus.

What kind of motion is it? We can confirm that this motion must meet one condition: it can produce an inertial centrifugal force to balance the electrical attractive force: "Inertial centrifugal force = (electrical attractive force)$_N$ ", otherwise, if it is $\succ$ or $\prec$, the electron will fall to the nucleus or run out of the atom. The subscript N indicates the direction that perpendicular to the track. Therefore, the motion is certainly not decided by the velocity that satisfies the uncertainly principle, because the principle gives infinite possibilities; no stable orbit can exist. In a word, there must be a definite orbit, otherwise the atom cannot exist.

Then we have to find out the orbits. Because Rutherford α-particle scattering experiments show that the Columbus law of electrostatic fields still holds true within $10^{-14}\,m$; and the size of hydrogen atom is about $10^{-10}\,m$, so Columbus law can be used here, although the Rutherford modal of atom is outdated. Electron moving around nucleus is a Kepler problem. People have proved that under the conservation laws of energy and angular momentum, electrons orbits in the bound state $E \prec 0$ are elliptical. So, the electron cloud must be formed by these elliptical orbits. What we need to do next is to prove that the elliptical motion of electron does not radiate EM energy, does not fall to the nucleus; and to explain how the elliptical orbits form the clouds.

However, there is an objection, for example from the wiki: Electrons move at high speed in a very small space outside the nucleus. Their motion rules are different from those of ordinary objects, and they do not have a clear trajectory. According to the uncertainty principle in quantum mechanics, we cannot accurately measure the position and speed of an electron at a certain moment, nor can we draw its trajectory. Can this objection hold?

The matrix mechanics appeared earlier than the wave mechanics, Heisenberg assumes that the classical concept of motion is not applicable at the quantum level. Electrons bound inside atoms do not have clearly defined orbits, but move in unclear and unobservable orbits. Only energy levels are meaningful, and then, he arranged the hydrogen spectral series into a matrix and established matrix mechanics.

As far as I know, in the process of Heisenberg establishing the matrix mechanics, he didn't involve the content: the trajectory is clear or not clear or does not exist. He assumes only physical quantities that can be observed in experiments have physical meaning and can be described by theory. Everything else is nonsense. His purpose is to show that "only energy levels of electrons" are meaningful. Besides, Heisenberg had not used the uncertainty principle to question Schrödinger's computation, although the quantities in the Schrödinger's computation cannot be observed in experiments. In fact, although wave mechanics involves unobservable quantities, its achievements and potentiality are far more than the matrix mechanics. Because the discrete energy level is the basic of matrix mechanics; and the discrete energy level is the inference of the Schrödinger equation. Is there any credible reason that the assumption of matrix mechanics is qualified to question the processes and results in the Schrödinger computation? So, above objection does not have a reliable basis.

Besides, not clear orbit or no orbit cannot meet the condition: "Inertial centrifugal force = (electrical attractive force)$_N$ "; it will destroy the atom. So, above objection is not valid, we think. We had better depend on experiments to discriminate whether the different opinion can be acceptable; not depend on an assumption to deny different opinion.

On the other hand, because we don't have the photo of a moving electron itself, what we have is the photo of electron cloud. So in order to understand what does the photo of electron cloud mean, we hear have to start from the indivisibility of charge quantum $-e$: The electron only have a single position at any moment. Although in this paper the electrons themselves have double helix structure, the positions of their mass center are still indivisible.

We try to abandon the accuracy of position in the photo to say: in the photo, a static electron should form a point; a slow electron should form a short line; a rapid electron should form a long line. Even in the cloud chamber, the trajectory of a beta ray must be inside the trajectory of the mist drops; it is this beta trajectory that causes the appearance of the mist drops. In other words, the electrons as rapid as in the cosmic ray still have a trajectory. So, if neglect accuracy, we can say: the line on the photo is a proof of the existence of electron's trajectory.

Then, if the electron velocity is extremely rapid, and if this line is far longer than a circumference around the nucleus it may form a group of overlapping ellipses or a Lissajous figure; the latter is like a cloud, the electron cloud.

Why the rapid electrons do not fall to the proton due to EM radiation? Let us discuss in the following:

In the Schrödinger successful computation of the hydrogen spectral series in 1926, the computation showed that for the electron in bound state $E \prec 0$, only when

$$E_n = -\frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n^2}\right) \quad (n=1,2,3,...), \tag{62}$$

the wave function $\psi(x,y,z,t)$ in the Schrödinger equation have the solution $\mathrm{E}_{nlm}(r,\theta,\varphi) = R_{nl}(r)\,\Upsilon_{lm}(\theta,\varphi)$ that can satisfy the standard conditions of the wave function. Different n represent different energy levels.

On the other hand, because the Coulomb electric field produced by proton is central symmetry, so the orbit of electron is a symmetrical plane curve. What kind of curve is it? Recall the old quantum epoch, Summerfield used the quantum conditions $\oint p_r dr = n_r \hbar$, $\oint p_\vartheta d\vartheta = n_\vartheta \hbar$ and $\oint p_\psi d\psi = n_\psi \hbar$ to prove that the electron energy levels in hydrogen atoms are discrete $E_n = -\frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n^2}\right)$, as same as the Eq.(62); and have corresponding elliptical orbits. Compare these results to the above; we can think that the symmetrical plane curves of electrons are elliptical.

As well known, in the main shells (the Eigen states) of a multi-electron atoms there are at most $2n^2$ electrons. Due to $m_s = \pm 1/2$, so they are consisted of n^2 $m_s = 1/2$ (right-hand) electrons and n^2 $m_s = -1/2$ (left-hand) electrons. They form n^2 pairs of right handed electron and left handed electron. Two kinds of electrons $m_s = \pm 1/2$ have different directions of magnetic pole perpendicular to the O-planes.

Owing to the spherical symmetry of the field in which the electron moves and because the electron angular velocity $\vec{\omega}(=2\pi\vec{\nu})$ and electron spin $m_s = 1/2$ and $m_s = -1/2$ are all perpendicular to the O-plane, it has no contribution to the orbital angular momentum L (parallel to the O-plane). Only the orbital motion can generate the orbital angular momentum. So the electron orbital motion around the proton is nothing to do with the directions of electron spin $m_s = 1/2$ and $m_s = -1/2$.

There is a problem happened: If electrons have elliptical orbit, it must have an acceleration and EM radiation, why not fall to the nuclei?

To answer this problem, let's discuss the following situations:

(a) Take the electrons in the Eigen state $n, l = 1, m_l = 1, m_s = \pm 1/2$ as the first example. The resultant orbital angular momentum (correspondent to $l = 1,\ m_l = 1$) must be a sum of the two electrons' orbital angular momentum. Because of the demands $n, l = 1, m_l = 1$ at any time, so the $m_s = 1/2$ electron and $m_s = -1/2$ electron must have the same elliptical orbit and moving in the same direction along the ellipse.

Two electrons of the same category move along an elliptical orbit, the magnetic attraction from both sides of the electron will make them unstable and go together; at the same time, the magnetic attraction between the two electrons of the same category cannot overcome the electron kinetic energy at room temperature in general, therefore the state of aggregation is unstable (This is similar to the judgment of Pauli Exclusion Principle).

Only two electrons of different categories in the same elliptical orbit, the magnetic repulsions from two sides will cause any pair of $m_s = \pm 1/2$ electrons go to stable equilibrium and distribute at the two symmetrical points on the orbit. So let $x_1 = a\cos\alpha$, $y_1 = b\sin\alpha$ and $x_2 = a\cos(\alpha + \pi)$, $y_2 = b\sin(\alpha + \pi)$ represent their symmetrical initial positions at the orbit. Then their equations of motion are

$$x_1 = a\cos(\pm\omega t + \alpha)$$

$$y_1 = b\sin(\pm\omega t + \alpha) \tag{63}$$

And

$$x_2 = a\cos(\pm\omega t + \alpha + \pi)$$

$$y_2 = b\sin(\pm\omega t + \alpha + \pi) \tag{64}$$

Because of $(\frac{x_i}{a})^2 + (\frac{y_i}{b})^2 = 1 \quad (i = 1,2)$, their orbits are indeed elliptical. On the other hand, because $\sin(\alpha + \pi) = -\sin\alpha$ and $\cos(\alpha + \pi) = -\cos\alpha$, the resultant vibration of the $m_s = 1/2$ and $m_s = -1/2$ electrons is

$$x_1 + x_2 = a\cos(\pm\omega t + \alpha) + a\cos(\pm\omega t + \alpha + \pi) = 0 \tag{65}$$

$$y_1 + y_2 = b\sin(\pm\omega t + \alpha) + b\sin(\pm\omega t + \alpha + \pi) = 0 \tag{66}$$

The resultant vibration of the electrons pair is zero. That means when one electron in the pair radiates certain amount of EM energy it will absorb the same amount of energy from another electron at the same time. So any electron in this layer does not radiate a net EM energy to collapse into the nucleus.

(b) Because the difference between the two $n, l = 1, m_l = 1, m_s = \pm 1/2$ and $n, l = 1, m_l = -1, m_s = \pm 1/2$ quantum states is that they move in opposite directions on the same stable orbit, so they have the same conclusion: the electron in this layer radiates no net EM energy to collapse into the nucleus.

(c) It is evident that in the cases of $l = 2,3,\ldots$, the conclusions will be also the same. The electron does not radiate net EM energy to collapse into the nucleus. It is because of that the $l = 2,3,\ldots$, $m_l = \pm 2, \pm 3, \ldots$ represent there are two or three or even more pairs of different categories electrons distribute symmetrically on the ellipses; and the above assertion is available for any pair of them.

On the other hand, because the electron has a double helix distributed charge $-e$ around its symmetrical axis and it is a translational motion around the proton (not like the moon around the earth having an appropriate self rotation), so the angle between the symmetrical axis of the electron and proton changed periodically. It will make the force between the electron and proton, and then the elliptical orbit rotated around the proton vary periodically that makes the curve a bit like a Lissajous curve. It must be such a curve to form the electron cloud. The electron cloud photo reflects the probability distribution around the proton no matter whether measured or not. It also reflects that the probability distribution is a result of the electrons motions around the proton; therefore the probability distribution of electrons around the proton is causal.

Chapter XII Conclusion

To find out the inner structure of $\pm$ charged elementary particles and photons; and where do the spin and wave-particle duality of them come from and find out its physical mechanism; we first explore why the Schrödinger's computation could accurately reproduce the energy levels of the Bohr model; and find the general solution of free particle Schrödinger equation mathematically. We found it is because of the double helix structure of mass density plus partial self-rotation make the $\pm$ charged fermions quantized $\in = h\nu$ and a fixed value spin, right-handed $+\frac{2n+1}{2}\hbar \quad (n=1,2,...)$ or left-handed $-\frac{2n+1}{2}\hbar \quad (n=1,2,...)$. As for the photon, it is the double helix structures of vector E-H and EH-energy density of speed c make photons quantization $\in = h\nu$ and a fixed value spin $+\hbar$, or $-\hbar$;

There is a charge e distributes double helically along $\pm$ charged elementary particles side boundaries. This charge produces and carries a double helix E field to move together. They form a wave-particle hybrid structure. As for the photons, there is a pair of charges $\pm e$ distributed double helically along its side boundary; These charges produce and carry a double helix E field to move together and because of electromagnetic induction happens at velocity c, it becomes a ψ - (EH) wave. The photon and ψ -wave constitute a traveling wave-particle hybrid structure. On the other hand, because the interference fringes are formed by the random accumulation of particles on the screen according to the superposition state formed by the particles' ψ -wave, (rather than by the self-interference of particles). Therefore, it is such hybrid structures give $\pm$ charged elementary particles and photons wave-particle duality. Especially, such hybrid structures can exhibit wave property and particle property of these particles simultaneously in the same experiments. ψ - (EH) wave and E-wave are their probability waves. Their probability waves are produced by themselves.

The electrons in the Eigen states of hydrogen atoms have elliptical orbits. The translational motion of any electron makes the angle between the symmetrical axis of the electron and proton changed periodically. It makes the elliptical orbit rotated periodically around the proton to become the distribution as the electron cloud photo shows. It is such rotating curves to form the electron cloud. Probability distribution of electrons around the nucleus is causal.

Some people may question how classical physics used in this paper is qualified to discuss the quantum problems? For that, we can also ask a reverse question: Schrödinger equation itself like other differential equations does not have quantum character; why the Schrödinger equation plus the electron represented by a continuous wave $\psi(x,y,z,t)$ can become the basis of quantum mechanics? In fact, the criterion for whether the classical results can be accepted and beneficial to quantum physics depend on whether the experiments concern quantum phenomena can confirm the results.

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Appendix

Mathematical general solutions of the free particle Schrödinger equation.

For simplicity, let us discuss the free particle Schrödinger equations in one dimension:

$$i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial z}\ (=E\psi)\ \text{(A1)}$$

$$-i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial z}\ (=E\psi)\ \text{(A2)}$$

Because the Schrödinger equation is a wave equation, in mathematics, it has a general solution of the type $f(z-Vt)+f(z+Vt)$. Let us take $\psi(x,y,z,t)=\psi_0(x,y,z_0)\psi(z-Vt)\overset{let}{=}\psi_0(x,y,z_0)\psi(\zeta)$, ($\zeta=z-Vt$) as an example, we have

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi(x,y,z,t)}{\partial z^2}=-\frac{\hbar^2}{2m}\psi_0(x,y,z_0)\frac{\partial^2\psi(\zeta)}{\partial\zeta^2}(\frac{\partial\zeta}{\partial z})^2=-\frac{\hbar^2}{2m}\psi_0(x,y,z_0)\frac{d^2\psi(\zeta)}{d\zeta^2}\ (\zeta=z-Vt)\ \text{(A3)}$$

$$i\hbar\frac{\partial\psi(x,y,z,t)}{\partial t}=i\hbar\psi_0(x,y,z_0)\frac{\partial\psi(\zeta)}{\partial t}=i\hbar\psi_0(x,y,z_0)\frac{d\psi(\zeta)}{d\zeta}(-V)\ \text{(A4)}$$

If $B=\frac{d\psi(\zeta)}{d\zeta}$ and substitute Eq. (A3), (A4) into Eq. (A1), it gives $-i\hbar VB=-\frac{\hbar^2}{2m}\frac{dB}{d\zeta}$; or

$$B=\frac{d\psi(\zeta)}{d\zeta}=B_0e^{i\frac{4\pi mV}{h}(z-Vt)}\ \text{(A5)}$$

Then

$$\psi(\zeta)=\eta_0e^{i\frac{4\pi mV}{h}(z-Vt)}\ (\zeta=z-Vt)\ \text{(A6)}$$

The general solution of the free particle Schrodinger equation, Eq. (A1) in mathematics is a right "circular polarized" traveling wave beam

$$\psi(x,y,z,t)=\psi_0(x,y,z_0)e^{2\pi i(\frac{2mV}{h}z-\frac{2mV^2}{h}t)}=\psi_x+i\psi_y\ \text{(A7)}$$

Obviously the general solution of the free particle Schrodinger equation, Eq. (A2) in mathematics is a left "circular polarized" traveling wave beam

$$\psi(x,y,z,t)=\psi_0(x,y,z_0)e^{-2\pi i(\frac{2mV}{h}z-\frac{2mV^2}{h}t)}=\psi_x-i\psi_y\ \text{(A8)}$$

Where $V=\lambda_V\nu_V$ is the phase velocity; $\frac{2mV^2}{h}\overset{let}{=}\nu_V$ is the frequency; $\frac{h}{2mV}=\lambda_V$ is the wave length. $r\prec R$ Is the radius of the wave surface. Since the radius of the object must be finite, so $\psi(r\succ R)=0$.

Eq. (A7) and (A8) is a right "circularly polarized" traveling wave and left "circularly polarized" traveling wave respectively. Direct verification shows that eq.(A7) (A8) satisfies the Schrodinger equation; but any component of it, the plane wave ψ_x or ψ_y does not. So the necessary condition of a wave function $\psi(x,y,z,t)$ it can satisfy the Schrodinger equation is that it must be a circular polarized traveling wave (e.g. a photon), or it can form a circular polarized traveling wave.

We had better use particle's velocity u to replace the phase velocity V . Let the mass center of the particle (or particle system) represent the particle. Let $d\vec{r}$ be the displacement of the mass center Then the particle energy is $d\in=\vec{F}\cdot d\vec{r}=\frac{d\vec{p}}{dt}\cdot d\vec{r}=d\vec{p}\cdot\vec{u}\overset{\vec{p}//\vec{u}}{=}u\,dp$; so $\frac{d\in}{dp}=u$. Where $\vec{u}=\frac{d\vec{r}}{dt}$ is the group velocity (particle velocity); $\in_u=\frac{mu^2}{2}\overset{p_u=mu}{=}\frac{p_u^2}{2m}$ is the kinetic energy of the non relativistic particle. These two expressions of the kinetic energy must be equal $2mV^2=\frac{1}{2}mu^2$, so $u=2V$, and $\lambda_V=\frac{h}{2mV}=\frac{h}{mu}=\lambda_u$.

Then, the mathematical general solution of the free particle Schrodinger equation can be rewritten as the following circular polarized traveling waves

$$\psi(x,y,z,t)=\psi_x+i\psi_y=\psi_0(r)\,e^{2\pi i(\frac{z}{\lambda_u}-\nu_u t)} \quad (r=\sqrt{x^2+y^2}\le R,\ \lambda_u\nu_u=u,\ \lambda_u=\frac{h}{mu}=\frac{h}{p_u},\ \nu_u=\frac{mu^2}{2h}=\frac{\in_u}{h}) \text{ (A9)}$$

And

$$\psi(x,y,z,t)=\psi_x-i\psi_y=\psi_0(r)\,e^{-2\pi i(\frac{z}{\lambda_u}-\nu_u t)} \quad (r=\sqrt{x^2+y^2}\le R,\ \lambda_u\nu_u=u,\ \lambda_u=\frac{h}{mu}=\frac{h}{p_u},\ \nu_u=\frac{mu^2}{2h}=\frac{\in_u}{h}) \text{ (A10)}$$

Where ν_u and λ_u are the frequency and wave length of the particle expressed by the particle velocity u. The pitch of the particle's helix forms the wave length λ_u. The wave surface is particle's cross section. Owing to the beam's axial symmetry, we can use $\psi_0(r)$ ($r=\sqrt{x^2+y^2}\le R$) here to replace the amplitude $\psi_0(x,y,z_0)$ in the Eq. (A7), (A8).

We have noticed that the solution of the free particle Schrodinger equation, Eq. (A9), (A10) satisfy the de Broglie relation $\lambda_u=\frac{h}{mu}=\frac{h}{p_u}$ and