Electromagnetic Radiation and Stability of the Hydrogen Atom

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The hydrogen atom is a two-particle electromagnetic system controlled by the interaction between the electron and the proton. So a reliable description about electromagnetic phenomena in it should depend on treatment of the electromagnetic interaction of the periodically changing electric current elements caused by moving charged particles. As a result of pinch effect of the induced fields and interaction of displacement currents, the distribution and propagation of induced field are sharply restricted with increase of frequency, and the induced electric field could be pinched in a narrow tubular space, and at higher frequency it could spread on a bended path near the charged particle. The ground state of the hydrogen atom is a unique steady state, the balance state of mechanics, in which the radiation reaction in one charged particle is counteracted by the action of induced field caused by the other. For an isolated hydrogen atom, the ground state is the natural state; any lower energy orbit is prohibited by action of radiation field, and the higher energy orbit will go back to ground state because of spontaneous radiation. Orbit closure is a necessary condition for any steady orbit to satisfy. The modal response is the steady state of hydrogen atomic orbits. The electron jumps from the ground state to a modal orbit with high discrete energy by resonant absorption. The modal equation of the hydrogen atom was deduced by means of standing wave analysis, and selecting the ground orbit of the hydrogen atom as basic reference to describe the other modal orbits, then the modal equation was changed to the same mathematical form with the Schrödinger equation.

PACS 41.60.-m - Radiation by moving charges

1. Introduction

Light from the hydrogen atom, which is one kind of electromagnetic radiation caused by moving charged particles, is the most important data to understand the structure of the atom. Although there are numerous models to describe the electromagnetic phenomena based on quantum theory, classical electrodynamics, and classical electromagnetics, none of them can interpret the radiation of moving charged particle indisputably and completely. At present, the electromagnetic problems of the hydrogen atom are treated with the motion of single electron controlled by the central field of the nucleus, so the structure of the hydrogen atom is unstable because of the energy emission produced by accelerated electron.

But actually, radiation is determined by the induced electric field produced by change of magnetic field that relates to the motions of two charged particles. Clearly, the model of single accelerated electron cannot describe the two changing magnetic fields caused by the two charged particles. Therefore, the current understanding about the radiation of hydrogen atom is only an incomplete, or even incorrect, description.

In the atomic and molecular world, the charged particles are the ultimate sources of electromagnetic fields and radiation, and their motions are determined by the electromagnetic interactions among them. The hydrogen atom is the simplest atom, consisting of a proton and an electron, but it is a very complex electromagnetic system. Except for the ordinary Lorentz forces, the electromagnetic interaction in a hydrogen atom should include radiation reactions, interaction between radiations caused by different charged particles, the influence of radiation on motion of the other charged particles, and the action of induced magnetic fields on induced electric fields in radiation waves, *etc*. These effects are important factors for the correct description of motions of charged particles in the hydrogen atom.

The effect of spontaneous radiation on the motion of an accelerated charged particle could be described by the radiation reaction on it. According to conservation of energy, the radiation reaction force on an accelerated charged particle should make the energy of the charged particle decrease continuously, so its scalar product with the velocity must be negative at any time. The Abraham-Lorentz equation describes the radiation reaction of the charged particle deduced from Larmor's power equation, but the application of the equation is limited by additional conditions, and the problem of the 'runaway' solution. In [1] an integro-differential equation was induced to replace it, it but is contrary to the traditional concept of causality because of the 'pre-acceleration' predicted by this equation. So, the radiation reaction is still a difficult problem.

In terms of magnetic force of Ampere law, the magnetic force between two electric currents is a function of the two electric currents and the distance between them. The magnetic field of a moving charged particle could be understood with the effect of the electric 'current element'. For circular orbit motions of charged particles in the hydrogen atom, magnetic fields will change with rotation of the charged particles, and so induce electric fields. The change of magnetic force depends on the changes of magnetic fields, so with electromagnetic laws it is possible to build a relation between the intensity of the induced electric fields at the charged particles and the rate of change of the magnetic force.

Electromagnetic radiation is the propagation in space of a variable induced electric field with an induced magnetic field, and by means of Maxwell's theory the variable induced field could be regarded as displacement current. Clearly, the radiation fields caused by the charged particles in the hydrogen atom will act on each other, and could be understood by displacement currents. In addition, by the concept of the plasma pinch effect, the charged particles in plasma will be pinched by self magnetic field. So, the displacement current, which could be regarded as the effect of moving displacement charges, will certainly be pinched by self-induced magnetic field. Therefore, the interaction between induced electric fields and pinch effect in the hydrogen atom will obviously affect the distribution and the propagation of the radiation.

In this article, the electromagnetic radiation from hydrogen atom is discussed according to classical electromagnetics, based in detail on analysis of the electromagnetic interactions between the two variable electric current elements caused by moving electron and moving nucleus. Then the stability of hydrogen atom is also investigated. Finally, the modal response of the ground-state orbit of hydrogen atom is analyzed by means of a stationary-wave approach.

2. Spontaneous Radiation of a Hydrogen Atom

In a hydrogen atom, rotating around the centre of mass on itself circular orbit, the directions of the velocity and acceleration of the electron and the proton are rotating with the same frequency ν, while the magnitudes of them keep invariable. Fig. 1 shows the electron 'e' and the nucleus 'n' rotating counterclockwise around the center of mass on the xy plane, the center-of-mass is at the origin O of the coordinate frame. The Lorentz forces on the electron and nucleus provide the centripetal force to keep the balance of circular orbits. The electric current elements they form ($\mathbf{J}_\mathrm{e}$ and $\mathbf{J}_\mathrm{n}$) will rotate with the two charged particles, and produce changing magnetic fields, as well as inducing the electric fields.

According to classical electromagnetic theory, the magnetic force interacting between the electron and the proton is related to the product of the two electric current elements $\mathbf{J}_\mathrm{e}$ and $\mathbf{J}_\mathrm{n}$, and controls the changes of magnetic fields produced by $\mathbf{J}_\mathrm{e}$ and $\mathbf{J}_\mathrm{n}$, so the radiations of the two charged particles should relate to this product. At any time, the magnetic forces acting on the electron $\mathbf{F}_\mathrm{me}$ and on the nucleus $\mathbf{F}_\mathrm{mn}$ are the same in magnitude but opposite in direction, and the rates of change of the physical quantities related to velocity, such as $\mathbf{J}_\mathrm{e}$, $\mathbf{J}_\mathrm{n}$, $\mathbf{F}_\mathrm{me}$ and $\mathbf{F}_\mathrm{mn}$, are a factor $2\pi\nu$ times them in magnitude, and perpendicular in direction.

Because of rotation, additional electric currents are produced, and could be described by the rates of $\mathbf{J}_\mathrm{e}$ and $\mathbf{J}_\mathrm{n}$ that is $\dot{\mathbf{J}}_\mathrm{e}$ and $\dot{\mathbf{J}}_\mathrm{n}$ as shown in Fig. 2, while an additional force was acting on the charged particle. By Ampere's law, the additional magnetic forces on the electron $\mathbf{F}_\mathrm{re}$ and on the nucleus $\mathbf{F}_\mathrm{rn}$ can be described as follows:

$$\mathbf{F}_\mathrm{re} = \dot{\mathbf{J}}_\mathrm{e} \times \mathbf{B}_\mathrm{n} \quad , \quad \mathbf{F}_\mathrm{rn} = \dot{\mathbf{J}}_\mathrm{n} \times \mathbf{B}_\mathrm{e} \quad . \tag{1}$$

where, $\mathbf{B}_\mathrm{n}$ is the intensity of magnetic field of the nucleus at the position of the electron, and $\mathbf{B}_\mathrm{e}$ is the intensity of magnetic field of the electron at the position of nucleus. The directions of $\mathbf{F}_\mathrm{re}$ and $\mathbf{F}_\mathrm{rn}$ are opposite to the direction of their velocities, and their magnitudes are the same. Because $\mathbf{F}_\mathrm{re}$ and $\mathbf{F}_\mathrm{rn}$ are the effect produced by the changing magnetic field, so should be influence of induced electric field on the charged particles in terms of the concept of electromagnetic induction. With rotation, $\mathbf{F}_\mathrm{re}$ and $\mathbf{F}_\mathrm{rn}$ will do negative work on the charged particles, and make them slow down, thus they are the radiation reaction forces. The intensity of induced electric fields at the point of the charged particles could be described with $\mathbf{F}_\mathrm{re}$ and $\mathbf{F}_\mathrm{rn}$ divided by their charges, and only occur in the front of the charged particles. The electron and the proton possess the same magnitude of charge but opposite electrical property, then the induced electric fields of them are same in magnitude but opposite in direction.

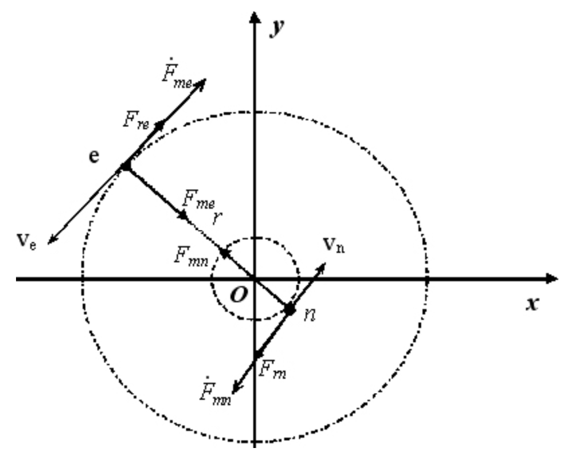

Figure 1. Electromagnetic interaction of the two moving charged particles in a hydrogen atom with a circular orbit. The center of mass of hydrogen atom is at the origin O of the frame; subscripts e and n represent electron and nucleus. r is the distance between nucleus and electron; $\mathbf{F}_\mathrm{m}$ and $\mathbf{V}$ represent magnetic force and velocity, respectively; $\dot{\mathbf{F}}_\mathrm{m}$ is the rate of the change of $\mathbf{F}_\mathrm{m}$; $\mathbf{F}_\mathrm{r}$ is radiation reaction; dash line represent the orbit of the particle.

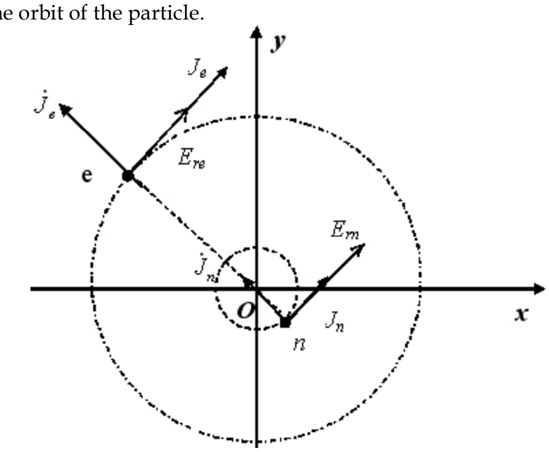

Figure 2. Electromagnetic interaction of the two electric current elements. Subscripts e and n represent electron and nucleus. E_r is the intensity of electric field induced by the moving charged particle, $\mathbf{J}$ is the electric current element, and $\dot{\mathbf{J}}$ is the rate of the change of $\mathbf{J}$; the dashed line is the orbit of the particle.

According to Faraday's law, the induced electric field $\mathbf{E}_{\mathrm{re}}$ should be proportional to $\dot{\mathbf{F}}_{\mathrm{me}} / e$, where the charge of the electron is $-e$. The magnitude E_{re} of $\mathbf{E}_{\mathrm{re}}$ at the point of the electron could be written as

$$E_{\mathrm{re}} = k_{\mathrm{i}} \dot{F}_{\mathrm{me}} / e \quad , \tag{2}$$

where, k_{i} is a coefficient related to electric induction. And the magnitude $\dot{F}_{\mathrm{me}}$ of $\dot{\mathbf{F}}_{\mathrm{me}}$ is:

$$\dot{F}_{\mathrm{me}} = 2\pi\nu J_{\mathrm{e}} B_{\mathrm{n}} = 2\pi\nu F_{\mathrm{me}} \quad , \tag{3}$$

where, F_{me} is the magnitude of magnetic force on electron, Combining formulae (2) and (3), the magnitude of E_{re} is described as

$$E_{\mathrm{re}} = (2\pi k_{\mathrm{i}} \upsilon / e) F_{\mathrm{me}} \quad . \tag{4}$$

Because the centripetal force of the circular motion of the electron is provided by the ordinary Lorentz force, which is a central force, and is inversely proportional to r^2, the squared distance between the electron and nucleus, and the frequency ν of the electron orbit is proportional to $r^{-3/2}$. So, the radiative reaction force F_{re} and the intensity of induction electric field E_{re} will increase rapidly with the diminution of distance r, and their rate of increase is sharplier than that of the Lorentz force.

According to Maxwell's electromagnetic wave theory, a changing electric field induces a magnetic field perpendicular to it, and could be understood as a displacement current produced by moving displacement charges. Because the vacuum of space is electrically neutral, the displacement current could be interpreted as the motion effect resulting from the same amount of negative and positive displacement charges moving in opposite directions. This description is similar to 'pinched-plasma': the plasma pinch effect is that the distribution and motion of charged particles in plasma are strongly restricted in a certain region by self magnetic field, and the intensity of the pinch effect is proportional to the square of self electric current [1]. Therefore, we could infer that the induced magnetic field would restrict the propagation and distribution of induced electric field like pinched plasma, and make the electromagnetic wave radiate in a very narrow area in front of moving charged particle at high frequency, as well as infer that the area of radiation will rapidly shrink with increase of frequency. Therefore, the spread characteristics of the periodic induced electric field is different from that of electrostatic of magnetostatic field because of 'pinch effect', and could radiate to a far distance without decrease of intensity of eletromagnetic fields.

It is not difficult to find that the displacement currents caused by radiation are parallel and in the same direction, and at the positions of the charged particles are in same direction with the currents caused by their motions. So the propagation of the induced electric field of one charged particle will be flexed by the magnetic force produced by the other charged particle, while the radiation will take away a part of the energy of the moving charged particles and make radius of the orbit shrink. With the decrease of radius of the orbit, the magnitude of the velocity, frequency and the displacement current will increase sharply, while the curving induced electric field of one charged particle will gradually approach to and act on the other charged particle. Finally, the induced electric field will meet with the other charged particle and push it ahead, and the push force will counteract the radiation reaction acting on the charged particle, then the propagation of the induced electromagnetic field will end at the charged particle, as shown in Fig. 3.

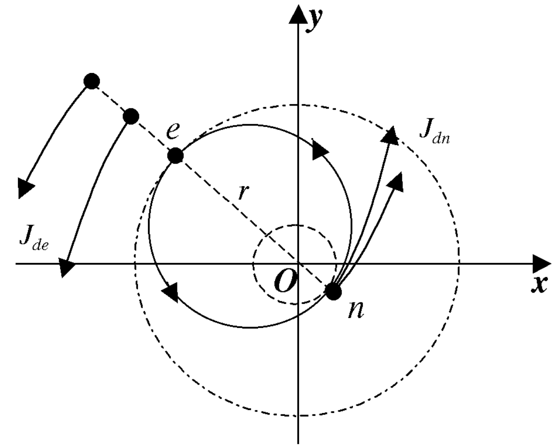

Figure 3. Interaction of displacement currents with different orbit radii. Subscripts e and n represent electron and nucleus. J_{d} is the displacement current; r is the radius of the hydrogen atom; dashed line is the orbit of the particle.

Thus, the hydrogen atom will not radiate energy to the outside, and the orbits of the electron and the nucleus will be steady. This effect could be called 'radiation couple of a pair of charges', the frequency of the orbit could be called 'cutoff frequency of radiation υ_{c}', and the cutoff radius of the electron orbit equals r_{c}. When $\upsilon > \upsilon_{\mathrm{c}}$ or $r < r_{\mathrm{c}}$, the curved induced electric fields will pass through the area between the electron and the nucleus, the magnetic forces between the moving charged particles and the displacement currents are repellent and will make the distance between the two charged particles increase. Therefore, unless the radius of the charged particles equals the cutoff radius, the hydrogen atom will be unstable. Of course, the cutoff radius r_{c} should be coincident with Bohr radius a_0 of the hydrogen atom.

For the noncircular closed orbits, the directions of electric current elements the two moving charged particles are parallel and change periodically, and the rate of the changes of the radial components of the two current elements are always in the same direction on a same line at any time. The inducing electric fields by them are always in same direction and change in synchrony, and the radiation field, which is the summation of them, will lose the energy of the hydrogen atom. Thus, the noncircular closed orbit is an unstable state with electromagnetic radiation.

3. Stability of the Hydrogen Atom

For an isolated hydrogen atom, the ground state, in which the electron and the nucleus rotate along their circular orbits with the cutoff frequency v_c, is the unique steady structure, the electron moving on higher energy orbit will automatically come back to ground state orbit by spontaneous radiation based on the discussion above. Clearly, this result satisfies to the lowest energy principle.

When a hydrogen atom is disturbed by the outer field, the orbits of charged particles must change to response and balance to the outer influence. An important necessary condition for the stability of the orbit is that the orbit be 'closed'. That is, starting from an arbitrary point on a steady orbit, the charged particles will return after a cycle to the same point, with the same state of motion.

The resonance of the ground orbit of hydrogen atom is one of steady response to the outer electromagnetic vibrating field, because the resonant orbit of the charged particles satisfies the closure condition. When the charged particle absorbs the energy of outer vibrating field with the same frequency with the ground orbit of hydrogen atom, the resonance of the ground orbit will take place, and the radiation of the electromagnetic field produced by the resonant orbit will balance with the outer field. Another response of the orbit is to change to a new orbit with a different frequency and absorbs the vibrating field energy with the special frequency that is part of the outer disturbing field. Clearly, this phenomenon could be understood as vibration response of the orbits of hydrogen atom, and be determined by the mechanical properties and the structure of ground orbit of hydrogen atom. By the knowledge of structural mechanics, modal vibration is a common natural phenomenon for an elastic object to response the outer periodic disturbs, and the modal frequencies are related to the natural frequency which is determined by the shape and elastic property of the elastic object. The ground hydrogen atom could be considered as a non-linear elastic structure that is controlled by center field force caused by the interaction between the electron and the nucleus. Therefore, the new orbits are only the higher energy orbits that satisfy modal response of ground orbit of hydrogen atom, and the modal frequencies could be described with the natural number and the frequency of ground orbit. The energy of the new orbits are certainly discrete, the radiation and absorption of electromagnetic wave of the hydrogen atom could be explained with the emission and absorption of periodic electromagnetic wave by the transition among modal orbits.

The ground circular orbit of hydrogen atom could be described with the compound motion of two orthogonal vibrations with the same amplitude and frequency, the modal response of the ground orbit could be solved by the vibration analysis. In terms of wave, the ground circular orbit of hydrogen atom could be understood as a tensed string, the modal response of it could be described by stationary waves. Thus, there are several mathematical approaches to be selected to treat the modal response of ground state hydrogen atom, and to interpret the structure and radiation of it.

4. Modal Analysis of Hydrogen Atom

In hydrogen atom, there are three kind interactions between the electron and the nucleus, such as coulombic force, magnetic force and radiation reaction caused by faradic electric field, and the magnetic force is very weak compared with coulombic force. So the effect of magnetic force was considered as modification for the result. Using the relative coordinate of the electron relative to the nucleus, the two-body system of hydrogen atom could be reduced one-body. Replacing electron mass with reduced mass $\mu = Mm/(M+m)$, where M is the mass of nucleus, and m is the mass of the electron. The electron motion relative to nucleus could describe the motion and potential energy of hydrogen atom.

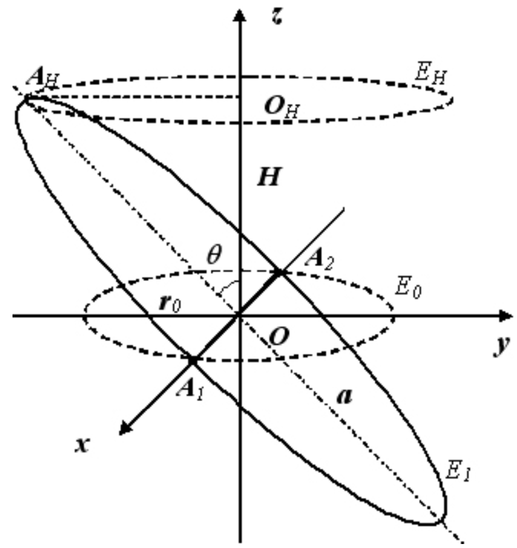

Figure 4. Vibration of the circular electron orbit along its normal direction. E_0 is the initial orbit (dash circle) with radius r_0; E_1 is the electron trajectory (solid ellipse) with transverse a; E_H is the vibrating orbit (dash circle); A_H is the farthest point of orbit E_1; O_H is the center of orbit E_H, H is resonate amplitude of orbit E_0 equals to the distance from O to O_H. A_1 and A_2 are the intersections of E_0 and E_1, and also are the nodes of standing wave.

Figure 4 shows a circular orbit with energy E_0 and radius r was put on the xy plane and nucleus was as origin of frame. It was resonating along its normal direction with natural frequency. E_1 is the trajectory of the electron and is similar to an ellipse, which could be considered as a standing wave based on E_0, the wave satisfied condition $2\pi r = n\lambda$, $n = 1$, that is the perimeter of the orbit E_0 equals to wavelength λ of the wave. Orbit E_H is the highest potential energy vibrating orbit of E_0; selecting curve coordinates of orbit E_0 and axis z, the axis OE_0 starts at node A_1, passes through node A_2 and ends at node A_1. As the frequency of orbit E_1 is same as that of orbit E_0 and keeps invariant, the orbit E_1 should be a harmonic wave with variable amplitude, and is similar to the standing wave of tense string as shown in Fig. 5. The approach of standing waves analysis for tense string could be introduced to describe the modal response of electron orbit in the hydrogen atom.

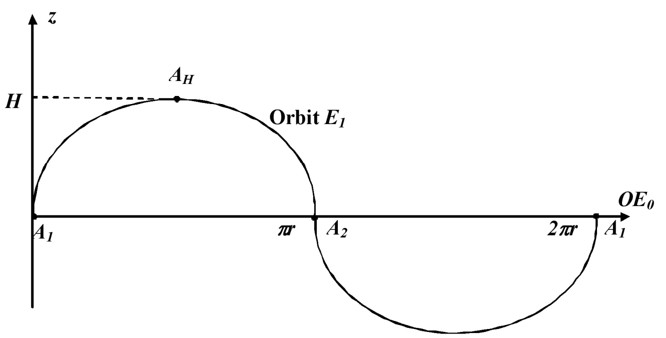

Figure 5. Harmonic wave of orbit E_1 relative to orbit E_0. A_1 and A_2 are the nodes of wave; A_H is the farthest point of orbit E_1.

Referring to the stationary wave equation for a tensed string, the space dependence part of the wave equation is as follows:

$$\partial^2 u(x) / \partial x^2 + (k / T_p) u(x) = 0 \tag{5}$$

or

$$\partial^2 u(x) / \partial x^2 + (2\pi / \lambda)^2 u(x) = 0 \quad , \tag{6}$$

and

$$k / T_{\mathrm{p}} = (2\pi / \lambda)^2 \tag{7}$$

$$k = \rho_{\mathrm{m}} \omega^2 \quad , \tag{8}$$

where k is the elastic coefficient, $u(x)$ and T_{p} represent, respectively, the wave function of the string and the tension acting on the string. ρ_{m} is the mass per unit length of string, and ω is the angular frequency.

The electron of hydrogen atom is controlled by coulombic force, magnetic force, and the action of faradic field. The equivalent elastic coefficient and tension of the electron should be very complex, and it is difficult to get the exact mathematical expression for them. A practicable way is to consider the main action of coulombic force, then to modify the result by the other two actions.

For any electron circular orbit, the centrifugal force equals the centripetal force, so the resultant force $F(r)$ should be zero and the tension T_{p} acting on the electron equals to the coulombic force:

$$T_{\mathrm{p}} = f_e = e^2 \big/ 4\pi\varepsilon_0 r^2 \quad . \tag{9}$$

$$F(r) = V / r + 2T / r = 0 \quad . \tag{10}$$

For a circular orbit, the elastic coefficient $k(r)$ is the derivative of $F(r)$, and can be deduced from Eq. (10):

$$k(r) = dF(r) / dr = -V / r^2 = 2T / r^2 \quad . \tag{11}$$

The circular electron orbit of ground state hydrogen atom is the foundation to analyze its modes, and could be considered as a standing wave with wavelength $\lambda = 2\pi r$ and with invariant amplitude. The tension acting on the electron T_{w} should equal T_{p},

$$T_{\mathrm{w}} = T_{\mathrm{p}} = e^2 \big/ 4\pi\varepsilon_0 r^2 \quad , \tag{12}$$

and elastic coefficient k_{w} is

$$k_{\mathrm{w}} = k(r) / 2\pi r = 2T / (2\pi r \cdot r^2) \quad . \tag{13}$$

Referring to formulae (5), (9) and (13),

$$\partial^2 u(x) / \partial x^2 + \left(4\pi^2 \varepsilon_0 \big/ 2\pi r e^2\right) 2T \cdot u(x) = 0 \quad . \tag{14}$$

The above formula is the wave equation of the circular orbit of hydrogen atom. Because the orbit could be at an arbitrary orientation in space, the spatial standing wave equation should be induced to describe the circular orbit of the electron orbit.

$$\nabla^2 \varphi(x, y, z) + \left(4\pi^2 \varepsilon_0 \big/ 2\pi r e^2\right) 2T \cdot \varphi(x, y, z) = 0 \quad , \tag{15}$$

where $\nabla^2 = \partial^2 / \partial x^2 + \partial^2 / \partial y^2 + \partial^2 / \partial z^2$

Comparing Eqs. (15) and (6), the wave length λ would be described as:

$$\lambda = h / P \quad . \tag{16}$$

where P is momentum of the electron, and

$$h = e\sqrt{\mu \pi r / \varepsilon_0} \quad , \tag{17}$$

$$\nabla^2 \varphi(x, y, z) + (4\pi^2 \mu / h^2) 2T \cdot \varphi(x, y, z) = 0 \quad . \tag{18}$$

Formula (17) and (18) is the mathematical expression in form stationary wave for ground circular orbit of hydrogen atom, but it is difficult to apply them to solve the structure of hydrogen atom. So, it is necessary for the mathematical expression to be treated for application.

By definition, any node on a stationary wave is at rest. So the energy of a stationary wave includes only potential energy. The circular orbit could be understood as a tensed string, and the motion of the electron produces centrifugal force for the balance of the orbit. The relation among the energy E of the stationary wave and the potential energy V, kinetic energy T of moving electron along orbit could be described as follow.

$$E = V = -2T = -4\pi^2 \mu \upsilon^2 r^2 \quad . \tag{19}$$

From formula (17) and (19), the energy of stationary wave is rewritten as

$$E = -h\upsilon \quad . \tag{20}$$

The hydrogen atom is the simplest atom; the structure of other atoms could be understood similarly as the electrons move in central field as like hydrogen atom. The treatment and solution of modal response of hydrogen atom could be used as reference to describe the other atoms. By the knowledge of modal response, the high term modal frequencies, energies and radius could be described with natural number and that of ground state. So, Bohr radius a_0 of ground state hydrogen atom could be treat as a constant, then

$$h = e\sqrt{\pi a_0 \mu / \varepsilon_0} \quad . \tag{21}$$

Calculating h with relative physical constants in formula (21), the result of h is

$$h = 6.62437 \times 10^{-34}\,\mathrm{JS} \quad . \tag{22}$$

Clearly, h is very close to Plank's constant. Replacing kinetic energy T with subtraction of potential energy V from total energy E, $T \to E - V$, formula (18) is written as

$$\nabla^2 \varphi(x,y,z) + \left(8\pi^2 \mu / h^2\right)(E - V)\varphi(x,y,z) = 0 \quad . \tag{23}$$

Formulae (20) and (23) are the equations used to solve the steady orbit of the hydrogen atom, and are of the same form as Plank's quantum hypothesis, and Schrödinger's equation. So, the solution of the hydrogen atom by Formula (20), (22) and (23) is certainly coincident to that from Schrödinger's equation.

5. Discussion

Classical electromagnetism is a perfect theory to interpret the electromagnetic phenomena of macroscopic charged objects and electric currents. The effect of electric current element of moving charged particle and the displacement electric current are important concepts to understand the electromagnetic field and wave. So, in this work, the radiation from hydrogen atom has been discussed with interaction between the two variable electric current elements of the electron and the proton, and the pinch effect of plasma was introduced to describe the propagation of the induced electromagnetic field. The treatment and consequence should be aligned to the classical electromagnetic theory.

In atomic and molecular systems, the charged particles are the ultimate sources of the electromagnetic fields and radiation. The motion of one charged particle is determined by the interaction between it and the others. And the radiation is completely controlled by interaction among the charged particles. And the action on a charged particle, including radiation reaction, is produced by the electromagnetic fields, and could be applied to describe the intensity and other properties of the electromagnetic field at the point that the particle locates. So, the radiation and the stability of a moving charged particle could be described by means of mechanical analysis.

Maxwell introduced the concept of displacement current in deducing his equations of electromagnetic fields. The electromagnetic wave is an important consequence from the equations, and was confirmed by Hertz' experiment. In addition, the electromagnetic wave could be interpreted as propagation of changing electric field along with changing magnetic field, by mutual inductance, and could be understood as a displacement current with self magnetic field that spreads in space in terms of the concept of displacement current.

According to the plasma pinch effect, the distribution and motion of charged particles in a plasma will be restricted by self magnetic fields. So, the propagation of changing electric field will be pinched by induced magnetic field, and the angle of radiation of electromagnetic wave will be controlled by this pinch effect. For a periodic orbital motion of charged particle in center electric field, the frequency will influence intensively on the radiation and pinch effect. At a lower frequency, the influence of the pinch effect of electromagnetic wave could be neglected, but at a higher frequency such as visible light, the propagation of radiation could be completely controlled by pinch effect and travels in a tubular space with invariable radius. In this situation, visible light could spread to far distant in vacuum without attenuation of field intensity. Clearly, the pinch effect of electromagnetic fields helps one understand the wave-particle duality of light.

At present, Quantum Mechanics (QM) provides an exact and complete theory for understanding the structure and the electromagnetic radiation of atoms and molecules. Schrödinger's equation [2], which is the wave-mechanics version of QM, has brought about outstanding consequences and provides a precise mathematical basis to explain the phenomena of atomic, molecular, and solid-state structure [3]. The important foundations of QM include Planck's quantum hypothesis [4] and the de Broglie wave [5]. But the debate about the interpretation of the de Broglie wave has never calmed down, and even extends to the philosophic domain. Currently, the Copenhagen interpretation developed by Bohr and his colleagues, including the purely probabilistic interpretation of the wave function [6,7], denies classical causality, causes the particle trajectory to disappear, and causes unpredictability in the observation of any quantity.

Not only were the founders of QM deeply perturbed, today some of the luminaries of science remain dissatisfied with its foundation and its interpretation, even in spite of acknowledging its stunning power [8]. Einstein [9] and Schrödinger [10] raised serious objections to the purely probabilistic interpretation, and Einstein believed that the theory was incomplete [11], and never accepted quantum theory.

Modal response of an elastic structure is a common phenomenon in nature. Atoms and molecules could be considered as non-linear elastic structures system controlled by Lorentz's force and radiation interaction among the charged particles, and as the steady balance system of mechanics and radiation. Modal frequencies are discrete, and the energies and radius of the modal orbits of the electron are discrete too. Therefore, modal response is the root cause that produces quantum phenomena in atomic and molecular world. In this work, Planck's hypothesis and Schrödinger equation have been deduced from the modal analysis of ground state of hydrogen atom, the mathematical relation $E = -h\nu$ was achieved under the condition that Bohr radius of hydrogen atom must be a constant. Therefore, for treatment of the structure of atoms and molecules, it is necessary to use the steady state of the hydrogen atom as a reference.

6. Conclusion

The electromagnetic radiation from hydrogen atom is produced by the electromagnetic interaction between the two changing electric current elements corresponding to the moving electron and the moving proton. The radiation reaction on the charged particles is an induction effect, and could be deduced from the change of magnetic interaction force. The radiation is the opposite effect to radiation reaction, and the intensity of the induced electric field at the location of the charged particle could be described with radiation reaction. The distribution and the propagation of the induced field are determined by pinch effect and interaction between the displacement currents. So, the radiations are restricted by the motions of the charged particles, and could act on them. These important physical phenomena cannot be neglected for comprehension of the electromagnetic effects generated by the moving charged particles in the hydrogen atom.

The steady orbits of the charged particles must satisfy the closure condition, *i.e.* the orbit is closed and rests in the center of mass frame of the atom. The ground state of the hydrogen atom is determined by the radiation counteraction of the pair of charges, and is the natural state of an isolated hydrogen atom. The orbits with higher energy are not stable because of spontaneous radiation of moving charged particles; only if there were appropriate disturbance of outer factors would the steady orbits with high energy possibly exist.

The resonant absorption and modal transition of the ground orbit are the important way for hydrogen atom enters into high-energy states. There are several mathematical approaches to treat the physical phenomenon, and with the waves the modal response of ground orbit of hydrogen atom is described easily. Selecting the ground orbit of hydrogen atom as the basic reference, the mathematical expression of modal response was simplified for treatment. The relation between energy and frequency, and modal equation in form of wave separately are in the same form with Planck's quantum and Schrödinger equation. Therefore, the modal response of hydrogen atom could be used to interpret the exciting states and the linear spectrum of hydrogen atom.

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What Experiments on Diffraction of Photons Say

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Experiments on diffraction of photons point to a problem in theoretical physics, but the idea of force-free circular motion brings about a possible solution to the trouble. With a proper understanding of motion, emission theory becomes a viable concept. Thus, it is feasible that waveforms in the transmission of light are produced by the motion of the emitter. (See [6].) Accordingly, packets of photons could serve as a model to explain diffraction and interference phenomena of light.

All radiation from Earth maintains the circular motion of Earth itself; including Earth's daily spin, its orbit around the Sun, and so on. The geometry of force-free circular motion combined with motion in a straight-line is determined by the speed and the direction of each motion with reference to the other. For this reason, the direction in which a light source on Earth is pointed will affect the course of its light rays. This was confirmed by the Brazilian experiment, in which a laser beam mounted on a turntable system scanned actively in space by turning the table.

The Brazilian experiment also used a laser beam fixed in a laboratory frame that scanned in space due to Earth's rotation. The Earth's daily spin alternately agrees with and opposes the direction of its orbit. Consequently, the overall motion of the Earth is not uniform, but is in fact constantly changing. This irregular motion was detected by the Brazilian experiment. Indeed, the apparent speed of light is constant relative to the non-rotating ECI frame, but its direction will change as the direction of the Earth's daily spin changes with reference to its orbit. And so in conclusion, these tests on diffraction of photons could be telling us that the entire foundation of theoretical physics is wrong.

Cern, the world's largest physics lab, recently announced that a neutrino beam fired from a particle accelerator near Geneva to a lab 454 miles away in Italy travelled 60 nanoseconds faster than the speed of light [8]. A speed as such goes against special relativity theory, but it may very well agree with principles of force-free circular motion. According to those principles, a neutrino beam fired from Earth travels in a naturally curved path due to Earth's axial rotation. Thus, those particles curve into the same general direction in which the Earth and its cities rotate. Yet any curve in the path of a neutrino becomes less curved relative to cities on Earth because those cities move in a similar path of their own. Moreover, a curved path which becomes less curved also becomes shorter to travel, while the speed of a neutrino remains unchanged relative to its source of emission. As a result, the apparent speed of a neutrino, or the magnitude of its average velocity, becomes faster than c relative to cities on Earth. And so is this to be interpreted as the effect of 'time dilation'? Or has Cern found a problem with special relativity?

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