Electromagnetic radiation and steady states of hydrogen atom

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Abstract. Electromagnetic phenomena in hydrogen atom are controlled by the electromagnetic interaction of the moving charged particles and the induced fields. The effects of self concentration and bend of propagation of induced fields will produced by pinch effect and interaction of displacement currents with increase of frequency. The ground state of hydrogen atom is the natural mechanical balance state which the radiation reaction on the charged particle was counteracted by the radiation action of the other. The modal response of the orbits is steady state of hydrogen atom with high energy, and the modal equation of ground orbit could be deduced by means of standing wave analysis. Selecting the ground orbit of the hydrogen atom as basic reference to describe the modal orbits, the modal equation would be changed into the same form with Schrödinger equation. Therefore, the modal response could be applied to explain excited states and electromagnetic radiation of hydrogen atom.

Key words: Electromagnetic radiation, Moving charged particle, Pinch effect, Modal response, Standing wave, Schrödinger equation

Contents

1. Introduction

Light from 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, but none of them can interpret the radiation of moving charged particle indisputably and completely. At present, the electromagnetic problems of a hydrogen atom is treated with the motion of single controlled by the center field of the nucleus, so the structure of hydrogen atom is unsteady because of the energy emission produced by accelerated electron. Actually, radiation is determined by the induced electric field produced by change of magnetic field which relates to the motions of two charged particles. Clearly, the model of single accelerated electron can not describe this two changing magnetic fields caused by the two charged particles, thereby; the current understanding about the radiation of hydrogen atom is only an incomplete or even incorrect description.

In atomic and molecular world, the charged particles are the ultimate sources of electromagnetic field and radiation, and their motions are determined by the electromagnetic interactions among them. Hydrogen atom is the simplest atom, which consists of a proton and an electron, but 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 field on induced electric field in radiation wave etc. These effects are important factors for the motions of charged particles in hydrogen atom to be described correctly.

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 loss continuously, so its direction must be in inverse direction of its velocity at any time. 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 "runaway" solution. An integrodifferential equation was induced to replace it, but is contrary to the traditional conception of causality because of the "preacceleration" predicted by this equation[1]. So, the radiation reaction is still a difficult problem to be solved. In terms of magnetic force of Ampere law, magnetic force between two electric currents is determined by two electric currents and their distance, 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 hydrogen atom, magnetic fields will change with rotation of the charged particles, and while induce electric fields. The change of magnetic force depend on the changes of magnetic fields, so it is possible to build a relation between the induced the intensity of electric fields at the charged particles and the rate of the change of magnetic force by electromagnetic laws.

Electromagnetic radiation is the propagation of variable induced electric field with induced magnetic field in space, and the variable induced field could be regarded as displacement current by means of Maxwell's theory. Clearly, the radiation fields caused by the charged particles in hydrogen atom will act each other and could be understood by displacement currents. In addition, by the conception of pinch effect of plasma, 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 will obviously affect the distribution and the propagation of the radiation in hydrogen atom.

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

2. Spontaneous radiation of 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 υ, but the magnitudes of them keep invariable. Figure 1 shows the electron e and the nucleus n rotate counterclockwise around center of mass on plane xy, the centre-of-mass is at the origin O of the frames. The Lorentz's forces on the electron and nucleus provide the centripetal force to keep the balance of circle orbits. The electric current elements of them (J_e and J_n) will be rotating with the two charged particles and producing an changing magnetic field, as well as inducing the electric fields.
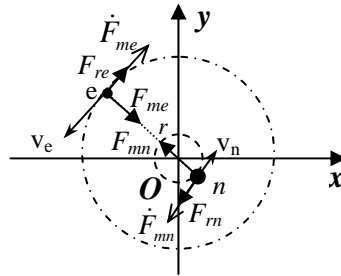

Figure 1. Electromagnetic interaction of the two moving charged particles in hydrogen atom with circle orbit. The center of mass of hydrogen atom is at the origin O of the frame; subscript e and n represent electron and nucleus. r is the distance between nucleus and electron; F_m and V represent magnetic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

According to classical electromagnetics theory, the magnetic force interacting between the electron and the proton is related to the product of two electric current elements J_e and J_n, and controls the changes of magnetic fields produced by J_e and J_n, so the radiations of the two charged particles should relate to this product. At any time, the magnetic forces acting on the electron F_{me} and on the nucleus F_{mn} are same in magnitudes but opposite in direction, and the rates of changes of the physical quantities related to velocity are $2\pi\nu$ times of them in magnitude and perpendicular in direction, such as J_e, J_n, F_{me} and F_{mn}. Because of rotation, the additional electric currents were produced and could be described by the rates of J_e and J_n that is $\dot{j}_e$ and $\dot{j}_n$ as shown in figure 2, while an additional force was acting on the charged particle. By magnetic force of Ampere law, the additional forces on the electron F_{re} and on nucleus F_{rn} could be described as follow.

$$F_{re} = \dot{J}_e \times B_n$$

$$F_{rn} = \dot{J}_n \times B_e \tag{1}$$

Where, B_n is the intensity of magnetic field of the nucleus at the position of the electron, and B_e is the intensity of magnetic field of the electron at the position of nucleus. The directions of F_{re} and F_{rn} are in the oppsite direction of their velocities, and the magnitudes of them are same. Because F_{re} and F_{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 rotating, F_{re} and F_{rn} will do negtive work to the charged particles and make them slowdown, thus are the radiation reaction forces. The intensity of induced electric fields at the point of the charged particles could be described with F_{re} and F_{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 oppsite electrical property, then the induced electric fields of them are same in magnitude but in oppsite dirction.
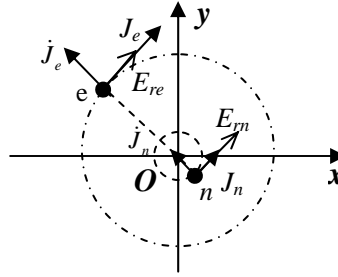

Figure 2. Electromagnetic interaction by the two elctric current elements. subscript e and n represent electron and nucleus. E_r the intensity of induced electric field by moving charged particle; J is the electric current element and $\dot{J}$ is the rate of the change of J; dash line represent the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

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

$$E_{re} = k_i \frac{\dot{F}_{me}}{e} \tag{2}$$

Where, k_i is a coefficient related to electric induction. And the magnitude of $\dot{F}_{me}$ is as follow,

$$\left|\dot{F}_{me}\right| = 2\pi \nu J_e B_n = 2\pi \nu \left|F_{me}\right| \tag{3}$$

Where, $\left|F_{me}\right|$ is the magnitude of magnetic force on electron, Combining formula (2) and (3), the magnitude of E_{re} is described as

$$\left|E_{re}\right| = \frac{2\pi k_i \upsilon}{e} \left|F_{me}\right| \tag{4}$$

Because the centripetal force of the circle motion of the electron is provided by the ordinary Lorentz's force which is center force, and is inversely proportional to r^2 the square distance between the electron and nucleus, and the frequency ν of orbit of the electron is directly proportional to $r^{-3/2}$. So, the radiative reaction force F_{re}

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and the intensity of induction electric field E_{re} will increase rapidly with the diminution of distance r, and the speed of increase of them is sharplier than that of Lorentz's force.

According to Maxwell's electromagnetic wave theory, a changing electric field induces a magnetic field rotating it, and could be understood as a displacement current produced by moving displacement charges. Because the vacuum space is electrically neutral, the displacement current could be interpreted as the motion effect by the same amount of the negtive and positive displacement charges which move in oppsite direction. This description is similar to the pinched-plasma, the pinch effect of plasma 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 give the deduction that the induced magnetic field would restrict the propagation and distribution of induced electric field like pinhed plasma, and make the electromagnetic wave radiates in very narrow area in front of moving charged particle at high frequency, as well as 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 far distance without decrease of intensity of eletromagnetic field.
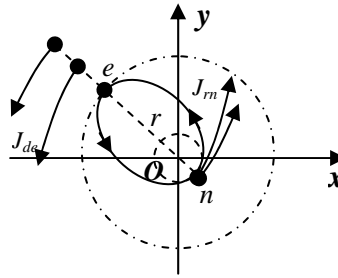

Figure 3. Interaction of displacement currents with different radius of circle orbit. subscript e and n represent electron and nucleus. J_d is the displacement current; r is the radius of the hydrogen atom; dash line represent the orbit of the particle.

It is not difficult to find 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 by their motions, So the propagation of 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 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 figure 3. Thus, hydrogen atom will not radiate energy to outside, and the orbits of the electron and the nucleus will be steady. This effect could be called radiation couple of pair of charge, the frequency of the orbit could be called cutoff frequency of radiation υ_c, and the cutoff radius of the electron orbit equals to r_c.

When $\upsilon > \upsilon_c$ or $r < r_c$, the curved induced electric fields will pass throught 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 equal the cutoff radius, hydrogen atom will be unsteady. Of course, the cutoff radius r_c should be coincident with Bohr radius a_0 of 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 synchronistically, and the radiation field which is the summationof them will loss the energy of hydrogen atom. Thus, the noncircular closed orbit is unsteady state with electromagnetic radiation.

3 Stability of hydrogen atom

For an isolated hydrogen atom, the ground state which the electron and the nucleus rotate along their circular orbits with the cutoff frequency υ_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 was disturbed by the outer field, the orbits of charged particles would change to response and balance to the outer influence. An important necessary condition for the stability of the orbit is that a steady orbit is rest and closed. That is, starting from an arbitrary point of a steady orbit, the charged particles will go back to the starting point with the same state after a cycle.

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 closedness 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 which 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 which 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 which 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 the 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 red uced mass μ, $\mu=Mm/M+m$, 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.
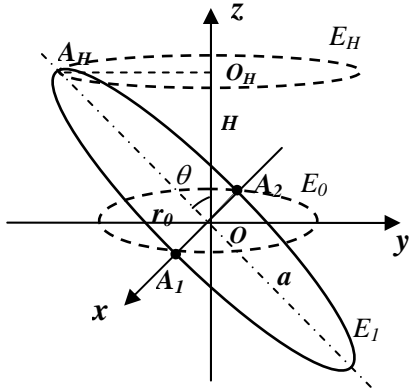

Figure 4. Vibration of the circular electron orbit along its normal direction. E_0 is the initial orbit (dash circle) with radius r_0; E_1 is the electron trajectory (solid ellipse) with transverse a; E_H is the vibrating orbit (dash circle); A_H is the farthest point of orbit E_1; O_H is the centre 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 xy plane and nucleus was as origin of frame. It was resonating along its normal direction with natural frequency. E_1 was trajectory of the electron and was similar to 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 with that of orbit E_0 and keeps invariable, 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 figure 5. The approach of standing waves analysis for tense string could be introduced to describe the modal response of electron orbit in hydrogen atom.
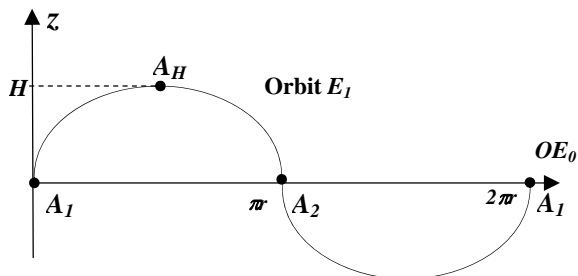

Figure 5. Harmonic wave of orbit E_1 relative to orbit E_0. A_1 and A_2 are the nodes of wave; A_H is the farthest point of orbit E_1

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

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

Or

$$\frac{\partial^2 u(x)}{\partial x^2} + \left(\frac{2\pi}{\lambda}\right)^2 u(x) = 0 \tag{6}$$

And

$$\frac{k}{T_p} = \left(\frac{2\pi}{\lambda}\right)^2 \tag{7}$$

$$k = \rho_m \omega^2 \tag{8}$$

Where, k is elastic coefficient, $u(x)$ and T_p represent respectively the wave function of 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 acting 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 of them. A practicable way is to consider the main action of coulombic force, then to modify the gotten result by the other two actions.

For any electron circular orbit, the centrifugal force equals to 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:

$$T_p = f_e = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2} \tag{9}$$

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

For the circle orbit, the elastic coefficient $k(r)$ is the derivative of $F(r)$ and could be deduced from the equation (10)

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

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 an invariable amplitude. The tension acting on the electron T_w should equal to T_p, elastic coefficient k_w is as follow.

$$T_w = T_p = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2} \tag{12}$$

$$k_w = \frac{1}{2\pi r} k(r) = \frac{2T}{2\pi r \cdot r^2} \tag{13}$$

Referencing to formula (5), (9) and (13),

$$\frac{\partial^2 u(x)}{\partial x^2} + \frac{4\pi^2 \varepsilon_0}{2\pi r e^2} 2T \cdot u(x) = 0 \tag{14}$$

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

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

Where, $\nabla^2 = \dfrac{\partial^2}{\partial x^2} + \dfrac{\partial^2}{\partial y^2} + \dfrac{\partial^2}{\partial z^2}$

Comparing equation (15) to formula (6), the wave length λ would be described as:

$$\lambda = \frac{h}{P} \tag{16}$$

Where, P is momentum of the electron, and

$$h = e \sqrt{\frac{\mu \pi r}{\varepsilon_0}} \tag{17}$$

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

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 the conception of stationary wave, any point on the stationary wave is at rest, the energy of a stationary wave only includes 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.

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

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

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

Hydrogen atom is the simplest atom, the structure of other atoms could be understood the problems that the electrons move in center 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

$$h = e \sqrt{\frac{\pi a_0 \mu}{\varepsilon_0}} \tag{21}$$

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

$$h = 6.62437 \times 10^{-34} \text{ J·S} \tag{22}$$

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

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

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

5. Discussion

Classical electromagnetis is a perfect theory to interpret the electromagnetic phenomena by macroscopic charged object and electric current. The effect of electric current element of moving charged particle and the displacement electric current are important conception 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 currents element 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 satisfied to the classical electromagnetics theory.

In atomic and molecular system, the charged particles are the ultimate sources of the electromagnetic field and radiation, the motion of a charged particle is determined by the interaction between it and the other. 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 field and could be applied to describe intensity and property of electromagnetic field of the point it locate. So, the radiation and the stability of moving charged particle could be described by means of mechanical analysis.

The conception of displacement current was introduced by Maxwell for deduction of Maxwell equations of electromagnetic field. Electromagnetic wave is an important consequence from the equations, and had been conformed by Hertz experiment. In addition, electromagnetic wave could be interpreted as propagation of changing electric field with changing magnetic field by mutual inductance, and could be understood as the displacement current with self magnetic field spreads in space in terms of conception of displacement current. According to the pinch effect of plasma, the distribution and motion of charged particles in plasma will be restricted by self magnetic field. 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 pinch effect of electromagnetic wave could 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 field is helpful to understand the wave-particle duality of light.

At present, quantum mechanics provides an exact and complete theory to understand the structure and the electromagnetic radiation of atom and molecule. Schrödinger equation [2] which is wave mechanics version of quantum mechanics 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 foundation of quantum mechanics includes 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 wave function [6, 7], denies classical causality, causes the particle trajectory to disappear, and causes unpredictability in the observation of quantity. Not only were its founders 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] aroused serious objections to the purely probabilistic interpretation, and Einstein believed that the theory was incomplete to describe the physical system [11], and never accepted quantum theory.

Modal response of elastic structure is a common phenomenon in nature. Atom and molecule could be considered as non-linear elastic structure system controlled by Lorentz's force and radiation interaction among the charged particles, and is 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 which produces quantum phenomenon in atomic and molecular world. In this work, Planck's hypothesis and Schrödinger equation have deduced from the modal analysis of ground state of hydrogen atom, the mathematic relation $E = h\upsilon$ was achieved under the condition that Bohr radius of hydrogen atom must be a constant. Therefore, it is necessary for treatment of the structure of atom and molecular to use the steady state of hydrogen atom as reference.

6. Conclusion

The electromagnetic radiation from hydrogen atom is produced by the electromagnetic interaction between the two changing electric current elements by the moving electron and the moving proton. The radiation reaction on the charged particles is the induction effect, and could be deduced from the change of magnetic interaction force. The radiation is the opposite effect to radiation reaction, and then 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 can not be neglected for the comprehension about the electromagnetic effects by moving charged particles in hydrogen atom.

The steady orbits of the charged particles must satisfy the closedness condition, i.e. the orbit is closed and rest in the center of mass frame of the atom. The ground state of hydrogen atom is determined by the radiation counteraction of the pair of charge, and is the natural state of an isolated hydrogen atom. The orbits with higher energy are not steady because of spontaneous radiation of moving charged particles, only if there is appropriate disturbance of outer factors, and the steady orbits with high energy would exist possibly. The resonant absorption and modal transition of ground orbit are the important way for hydrogen atom enters in 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 basic reference, the mathematical expression of modal response was simplied 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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