Original Research Article

THE NATURE OF PHOTON (STRUCTURE, SIZE, DUALITY)

ABSTRACT

Based on the Maxwell theory and the principle of charges quantization, we prove that for any definite ν, a symmetrical electromagnetic wave beam of minimum energy possesses the basic characters: $\in = h\nu$, $p = h/\lambda$, spin= $\hbar$ and duality. They are the good reasons for us to treat the wave beam as a photon. A photon is consisted of $\in$ -(energy)packet and ψ -(EM)wave. $\in$ -packet is a circular polarized electromagnetic field wrapped by a cylindrical lateral membrane with $\pm$ charge e. They form an extremely stable structure like a "solid particle". Under the protect of the membrane, no external electromagnetic field can break it or change its inner structure so as the photons can bring the information unchanged from the deep universe for over ten billion years. Photon ($\in$ -packet) of different frequencies ν have different radius $R_{\max} = \sqrt{3}c/2\pi\nu$ but same shape with same ratio $L/R \approx 0.04$ like a circular coin. The $\in$ -packet is floated on and carried by the ψ -(EM)wave to move together. ψ -wave decides and describes the probability behavior of the $\in$ -packet(s). Such structure unifies the duality of photons. Analysis of the pair production shows that symmetry will make the particles produced possess spiral structure of mass. The mass density on particles' cross section satisfy . $\sigma = \sigma_R(\frac{R}{r})^{\kappa}$.

Keywords:: nature of photon, cylindrical lateral membrane, $\in$ -(energy)packet, ψ -(EM)wave.

I. Introduction.

In 1905, Einstein first proposed that energy quantization was a property of electromagnetic radiation itself, [2] although he accepted the validity of Maxwell's theory. In 1909[3] and 1916[4], he showed that if Planck's law of black-body radiation is accepted, the quanta must also carry momentum $p = h/\lambda$, making them full-fledged particles.

The pivotal question was then: how to unify Maxwell's wave theory of light with its experimentally observed particle nature? The answer to this question occupied the rest of Einstein's life, [1] [5] although it was solved by the quantization way: quantum electrodynamics and its successor.

We used to think that waves and quanta, as two observable aspects of a single phenomenon can not have their true nature described in terms of any mechanical model.[6] [13] Is that final conclusion? Can we try to change the situation?

When a theory faced the facts that could not explain by itself, there are two possibilities: It needs a new theory or because the capacity of the theory have not developed perfectly.

Why Einstein thought highly of his way? We supposed it was because he deeply believed that Maxwell electromagnetic theory possesses high completeness and correctness and it is the theory **naturally** (need not modified) satisfy the Lorentz covariance, it must be extraordinary self-consistent. There isn't insurmountable obstacle between the Maxwell theory and modern physics. If there arise certain contradiction, it has enough capacity to solve them within theory itself. The wave nature and particle nature of light will be eventually unified and have a visual and satisfactory result. We also believe that**. What we did, in fact, is really a try to follow Einstein's expect**. The potential of Maxwell theory is beyond former expectations.

Energy quantization as a property of electromagnetic radiation itself, there must be a mechanism been oversight can make it. And there must exist a concrete physical mechanism or structure it causes the photon's wave particle duality;

We now start our study from the properties of a slim symmetrical electromagnetic wave beam. We do not presuppose it having any relation with the quantization and photon. What we did is based on the well known physical laws, although classical, and logical reasoning to see whether there is any relation between the electromagnetic wave beam and the photon; to see whether we can seek out more properties of them. Eventually, we found the photon's structure, shape, size and its relation with other particles.

II. The properties of a symmetrical electromagnetic wave beam and the structure, shape and size of the photons.

Far from a vibrating electric dipole of moment $\mathrm{M} = \mathrm{M}_0 \cos \omega t$ at point O: the field intensity is [7]

$$E(\rho, \vartheta, \nu, t) = \sqrt{\frac{\mu}{\varepsilon}} H = \frac{\pi M_0 \nu^2}{c^2 \varepsilon_0 \rho} \sin \vartheta \cos \omega (t - \frac{\rho}{c}) \quad (1)$$

Let us consider a slim symmetrical electromagnetic wave beam from the point O**. S**ymmetry refers to its wave surfaces circular and the beam conical. Let Ω be the solid angle. Distribution of field amplitudes over its wave surfaces can be generally written as $E_0(r, \rho, \nu) = \frac{A(r)}{\rho} \nu^2 \quad (\left|\frac{r}{\rho}\right| \le \frac{R}{\rho}, \frac{\pi R^2}{\rho^2} = \Omega)$ disregard of **r**-direction. r and R are the curvilinear distant and radius on the beam's wave surface at ρ.

Eq. (1) gives $E = H = 0$ when $\vartheta = 0$. Any symmetrical beam from point O will have $E = H = 0$ at tangent points if its lateral boundary is tangent to the line of $\vartheta = 0$. Because of the symmetry, such symmetrical beam's whole lateral boundary must be $E = H = 0$.

Further more speaking, any other symmetrical beams from O must have same $E = H = 0$ on the lateral boundary if its boundary tangent to the former and so on. Then we can affirm the **first feature** of the narrow symmetrical wave beams that existed in the field**: Their lateral boundary are always** $E = H = 0$.

A problem is that the wave beams with different size of Ω all satisfy the condition $E = H = 0$**,** is there existed a minimum Ω of the beams in the field it possesses this feature? We will give a definite answer at the end of this paragraph.

For convenience in the following, we name the geometrical plane (the synonym of the thin layer) as observation plane (O-plane) if a plane electromagnetic wave beam passes through it perpendicularly. Of course, for a spherical wave beam, the "O-planes" refer to spherical and coincides with the spherical wave surfaces.

Taking ρ as symmetrical axis, the equation of such narrow conical beam in the field from point O is

$$E(r,\rho,\nu,t) = A(\frac{r}{R})\frac{\nu^2}{\rho}\cos 2\pi(\frac{t}{T} - \frac{\rho}{\lambda}) \qquad (|r| \prec R) \quad (2)$$

It will excite a standing wave on the O-plane at point ρ_0 as follow

$$E(r,\rho_0,\nu,t) = A(\frac{r}{R_0})\frac{\nu^2}{\rho_0}\cos 2\pi\frac{t}{T}$$

$$(|r| \prec R_o, \quad t = t' - \frac{\rho_0}{c})$$

$$A(\frac{r}{R_0})_{r=R_0} = 0$$

$$(0 \prec R_0 \prec \infty) \qquad (3)$$

For any **r-**direction, the coefficient $A(\frac{r}{R_0})$ is always even function of r and equal to 0 at the boundary $r = \pm R_0$ (the first feature), it can be expanded in Fourier series as follow:

$$A(\frac{r}{R_0}) = \sum_{j=1}^{\infty} b_{2j-1}\cos 2\pi\,(2j-1)\frac{r}{4R_0}$$

$$\underset{=}{let} \sum_{j=1}^{\infty} b_{2j-1} \cos 2\pi \left(2j-1\right) \frac{r}{\Lambda}$$

$$(\Lambda = 4R_0 \; , |r| \leq R_0) \quad (4)$$

Substitute Eq. (4) into (3), we have

$$E(r, \rho_0, \nu, t) = \frac{\nu^2}{\rho_0} \sum_{j=1}^{\infty} b_{2j-1} \cos 2\pi (2j-1) \frac{r}{4R_0} \cos 2\pi \frac{t}{T}$$

$$= \frac{\nu^2}{2\rho_0} \sum_{j=1}^{\infty} [b_{2j-1} \cos 2\pi (\frac{r}{\Lambda_{2j-1}} - \frac{t}{T}) + b_{2j-1} \cos (\frac{r}{\Lambda_{2j-1}} + \frac{t}{T})] \quad \overset{let}{=} E_+(r - \nabla t) + E_-(r + \nabla t)$$

$$(\Lambda_{2j-1} = \frac{\Lambda}{2j-1}, \Lambda = 4R_0, \nabla = \frac{\Lambda}{T}, |r| \leq R_0,) \quad (5)$$

Symmetry demands b_{2j-1} and Eq. (4), (5) all disregard of **r**-directions.

For every moment t, **E** of all points on same O-plane are parallel, (Fig. 1) and varying synchronically. The radiation intensity of varying **E** is anisotropic. If the beam is linear polarized, the coefficients b_{2j-1} will be different in different **r**-directions. It is contradict to the symmetry of the amplitude $A(\frac{r}{R_0})$. Therefore, the beam must be circular polarized. It makes the time average of any coefficient b_{2j-1} on any O-plane to be rotational symmetry. **The second feature** of the symmetrical electromagnetic wave beam is**: it must be circular polarized (**right or left).

The beam's frequency ν equals to the number of **E**-rings every c meter in the beam itself. When the beam moves with speed c it will cause a rotating **E** of frequency ν on the O-planes and make its spin and energy.

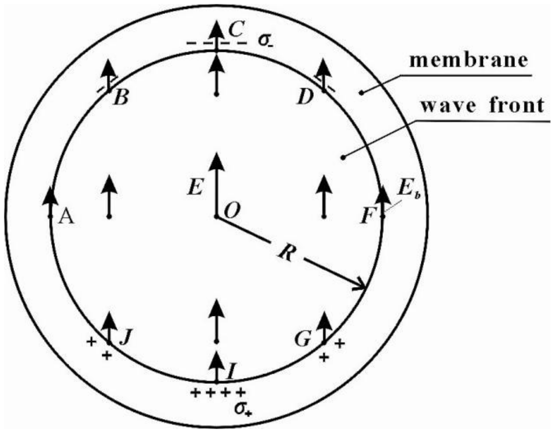

Fig. 1

The identity of equations (3) and (5) means when the wave beam passes O-plane at ρ_0, the energy excited in the thin layer can be treated as storage either in type of stationary vibration, or in type of the distribution of the infinite pairs of transversal traveling waves tangent to the O-plane [8], [9]. These tangential radiations along wave surfaces from varying **E** at all points on any O-plane are of course existed.

Equation (5) shows the resultant transversal waves on the O-plane are always radial. Any beam of the transversal traveling waves $E_+(r-\nabla t)$ or $E_-(r-\nabla t)$ is sector-like. Let $\delta\theta$ be the angle of the sector. Then for any sector of the beam $E_+(r-\nabla t)$, the energy flow passes through the area $r_i\,\delta\theta\,\delta\rho$ equal to the one passes through the $r_k\,\delta\theta\,\delta\rho$. That is

$$S_+(r_i,\theta,\rho,t)r_i\,\delta\theta\,\delta\rho = S_+(r_k,\theta,\rho,t)r_k\,\delta\theta\,\delta\rho$$

$$(0 \prec r_i \prec r_k \prec R) \qquad (6)$$

Since Poynting Vector, $S_+ = \sqrt{\frac{\varepsilon_0}{\mu_0}}E_+^2 = \sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{A^2(\frac{r}{R})}{\rho^2}\nu^4$ let $r_i = r$, $r_k \to +R$ in Eq. (6) and let $A_R = \lim_{\frac{r}{R}\to 1_-} A(\frac{r}{R}) = A(1)$ be the left limit at $r \to R$; then we have

$$A(\frac{r}{R}) = A_R\sqrt{\frac{R}{r}} \qquad (0 \prec r \prec R) \qquad (7)$$

For the beam $E_-(r+\nabla t)$ of reverse direction, Eq. (7) also holds. A_R is a constant disregard of the frequency ν, the magnitude of radius R and the direction of r on the wave surfaces.

The distribution of the energy density amplitude on the wave surfaces at ρ is

$$E^2 = E_R^2 \frac{R}{r} \qquad (0 \prec r \prec R) \qquad (7)^*$$

$E_R^2(\infty A_R^2)$ is the limit of energy amplitude at lateral boundary..

When $r \to \pm R_0$, the limits of $|E_+(r-\nabla t)|$ and $|E_-(r+\nabla t)|$ in Eq. (5) are same $A_R(\neq 0)$. But all $\left|\cos 2\pi(2j-1)(\pm\frac{r}{4R_0})\right|_{r=\pm R_0} = 0 \quad (j=1,2,...)$, it gives

$$|E_+(r-\nabla t)+E_-(r+\nabla t)|_{r=\pm R} \equiv 0 \qquad (8)$$

This boundary condition coincides with the beam's first feature. It means **whole lateral boundary is all the node points.** Incident transversal wave $E_+(r-\nabla t)$ (or $E_-(r-\nabla t)$**)** will be reflected back totally with 180^0 phase lost on the lateral boundary and becomes $E_-(r-\nabla t)$ (or $E_+(r-\nabla t)$). The lateral cylindrical boundary is really a surface of perfect reflection. Can the vacuum or field itself make such reflection? No! We will discuss them in the following.

Distribution of amplitude $A(\frac{r}{R})$ **with** r **satisfies Eq. (7) and lateral boundary is all consisted of node points, Eq. (8),** they are **third important feature** of the wave beam.

The wave beam's interaction probability with other particle at the center of the wave surfaces $\lim_{r\to 0} A_R\sqrt{\frac{R}{r}} \to \infty$ is absolutely far greater than other parts of the surface. It will give a definite result when the beam's position is measured. **The beam acts like a particle. The third feature makes and guarantees the particle like property of this wave beam**. Average amplitude of electric intensity over the beam's wave surface is $\frac{1}{\pi R^2}\int_0^R A(\frac{r}{R})2\pi r\,dr \overset{(7)}{=} \frac{4}{3}A_R$. If it equals to $\frac{1}{n}(\frac{\pi \mathrm{M}_0}{c^2\varepsilon_0})$ in compare with Eq.(1) and (2), we have

$$A_R = \frac{3\pi}{4c^2\varepsilon_0}\frac{\mathrm{M}_0}{n} \overset{let}{=} \frac{3\pi M_0}{4c^2\varepsilon_0} \qquad (M_0 = \frac{\mathrm{M}_0}{n}) \qquad (9)$$

Here n is just a ratio, integer or not is waiting to be determined (ref. to the part of the seventh important feature). Eq. (9) means the moment M_0 will produce n beams within the angle Ω in $\vartheta = \frac{\pi}{2}$ direction; M_0 will produce one beam disregard of what ν it is.

From Eq. (2), the average energy $\in = \in(\nu)$ per unit length of the wave beam is[7]

$$\frac{d\in}{d\rho} = \frac{1}{2}\int_{r=0}^{R} \frac{\varepsilon_0 A^2(\frac{r}{R})\nu^4}{\rho^2} d\sigma_r \qquad (10)$$

Here $d\sigma_r = 2\pi\rho^2 \sin\varphi\, d\varphi (\approx 2\pi\, r\, dr)$. Let $\varphi = \frac{r}{\rho}$ and $\Phi = \frac{R}{\rho}$, they are the plane angles that arc r and radius R suspend at $\rho = 0$. Then

$$\frac{d\in}{d\rho} = \int_{\varphi=0}^{\Phi} \pi\varepsilon_0 A^2 (\frac{\varphi}{\Phi}) v^4 \sin\varphi\, d\varphi = v^4 F(\Phi) \qquad (11)$$

The beam's energy is always inside the angle $\Omega = \int_0^{\Phi} 2\pi\rho^2 \frac{1}{\rho^2} \sin\varphi\, d\varphi = 4\pi \sin^2 \frac{\Phi}{2}$ disregard of ρ. The propagation direction of the wave beam's energy is radial.

A problem is: if a common wave beam is moving lonely in the free space, can it keep the solid angle Ω constant? The answer in general is of course "No". Wave property will make it spread out. The next question is "Does there exist a special kind of symmetrical wave beam it can always keep solid angle constant lonely in the free space?" If the answer is negative, then any electromagnetic wave beam ($0 \prec v \prec \infty$) will spread out forever so as no one can receive meaningful information from the deep universe. It is contrary to the observation facts. The conclusion is in order to receive meaningful information from the universe, at least there must exist a kind of symmetrical electromagnetic wave beams in reality that can always keep constant Ω and carry meaningful information lonely through the free space. We call it as special (electromagnetic) wave beam for convenience.

How can the special wave beam keep the Ω constant? The only way is its lateral boundary possesses same property as Eq. (8), it can totally reflect back all outward energy and keep the energy inside the solid angle Ω. Lateral boundary becomes a set of node points. Since reflection can not happen between vacuum, the only possibility is there must be a material accompanied from the source that covers the beam's lateral boundary to play this role. We call it membrane for convenience. Special wave beam's **lateral boundary must be covered by a membrane of perfect reflection and zero rest mass.** This is **the forth important feature** of the special electromagnetic wave beam. It is such membrane makes the existence of independent wave beams.

The existence of the membrane is of no surprise. Photon, the energy packet as we used to think it also need a carrier or a shell of protection (certain material) to protect it from spreading and the influence of outer electromagnetic field. In fact, the membrane can be really an energy carrier or the shell.

Since special electromagnetic wave beam possesses constant solid angle Ω like the conical beam in the field, Eq. (2) it is of course possessing the third feature, Eq. (7) and (8).

What we discuss in the following is all about the special electromagnetic wave beam. So we always simplify it as "wave beam" since now on.

The momentum rate of change $\frac{2S(R,\rho,\theta)}{c}$ perpendicular to the boundary on any wave surface will make a circular tension $T(R,\rho,\theta)$ in the membrane. Along the circumference, fig. 1 we have

$$T(R,\rho,\theta)=\frac{2R}{c}S(R,\rho,\theta)=\frac{2\Phi^2}{cR}\sqrt{\frac{\varepsilon_0}{\mu_0}}A_R^2\nu^4\cos^2\theta \quad (12)$$

Here θ is the angle between radius $\vec{R}$ and abscissa. $\vec{OF}$

The material of membrane must be very easy to change its shape during propagation, so we suppose it is a liquid-like material having almost constant volume. So the area $2\pi R\,\delta R \overset{let}{=} 2\pi\Gamma$ of the membrane cross section is constant. Its thickness is $\delta R=\frac{\Gamma}{R}$. Let $\Sigma_{\max}$ be the maximum normal stress on the cross-section of the membrane. Since $T_{\max}=\Sigma_{\max}\delta R$, it gives

$$\Sigma_A=\Sigma_F=\Sigma_{\max}=\frac{2\Phi^2}{c\Gamma}\sqrt{\frac{\varepsilon_0}{\mu_0}}A_R^2\nu^4 \quad (13)$$

This relation is valid for other points A and F on every wave surface. Connecting all these points A and F respectively, they form two parallel helixes on the lateral surface. Eq. (13) shows **maximum stress** $\Sigma_{\max}$ **along the double helix is invariant** during propagation despite of the magnitude of ρ and R **.** This is **the fifth feature** of the wave beam.

Since surface density σ of charge on the inner side of the membrane equals to $D_n=\varepsilon_0 E_n$ and $E_n=\frac{A_R}{\rho}\nu^2\sin\theta$, so for the upper spiral-half. Fig 1, the absolute value of σ_θ is

$$\sigma_\theta=\left|\varepsilon_0\frac{A_R}{\rho}\nu^2\sin\theta\right| \quad (0\le\theta\le\pi) \quad (14)$$

The points of same σ_θ on all wave surfaces form equal σ_θ-spiral. It means **the charges also distribute with helical symmetry** like the distribution of stress Σ **.** This is **the sixth feature** of the wave beam**.**

Charges and stresses make the membrane and inside electromagnetic field equilibrium and form a very steady structure to avoid external field influences. It is such structure make itself long life.

Total negative charge in the upper spiral-half is

$$q=\int_\rho^{\rho+L}d\rho\int_0^\pi\sigma_\theta R\,d\theta=2\varepsilon_0\Phi A_R\nu^2 L \quad (\Phi=\frac{R}{\rho}) \quad (15)$$

Here L interprets the length of the electromagnetic wave beam. The lower half have same amount of positive charge.

According to the **principle of charge quantization,** the wave beam can be an independent entity (like the particles, atoms, molecules…) in reality, only if it satisfies the condition $q = k\,e \qquad k = 1, 2, ...$ (we do not involve the quark theory)**.**

In compare with bigger charged area ($2\pi RL \infty \Phi L$) it having more charge $q = k\,e$ ($k = 2, 3, ...$), $q = e$ is the one of lowest energy, shortest train length and smallest lateral surface. Since now on, we let L be the shortest train length and $\in(\nu)$ express the lowest energy that the wave beams can possess for definite ν and name the train as elementary (special) train. **The elementary ν-train possesses $\pm$ charge e, shortest train length L and relative lowest energy $\in = \in(\nu)$.** In addition to the former features**,** this is **the seventh important feature** of the elementary train.

As an inference, charge quantization demands that the train with $q \neq ke \quad (k = 1, 2, ...)$ must not exist. Monochromic radiation field is certainly constituted of the trains with discrete energy $\in(\nu)$. In a word, electromagnetic energy is quantized**.** So the above number n in Eq. (9) must be integer.

Electromagnetic energy are really quantized as Einstein supposed in 1905. It is a natural inference of Maxwell theory plus the principle of charge quantization disregard what process the trains produced, quantum or not.

The increase of wave surfaces as the elementary train moves forward will cause the circumferences of membrane become longer and longer. Within $d\theta$ region, when the radius of the membrane increases from R to $R + d\,R$, the increment of circumference is $dR\,d\theta$. The work down in the $\delta\rho$-layer of the train against tension from original nucleus dimension R_0 to final R is

$$\delta W = \delta\rho \int_{R_0}^{R} 4 \int_0^{\frac{\pi}{2}} T(R, \rho, \theta)\, dR\, d\theta =$$

$$= \frac{2\pi \Phi^2}{c} \sqrt{\frac{\varepsilon_0}{\mu_0}}\, A_R^2\, \nu^4\, \delta\rho\, \ln \frac{R}{R_0} \qquad (16)$$

For any elementary ν-train, the work can be down against the tension is certainly finite. Utmost bound $R_{\max}$ of the radius R must exist, otherwise the train's lateral boundary will be broken. No meaningful information we can accept from far away. This contradicts to the observation facts.

When an elementary train just emitted from the vibrating electric dipole or other sources its energy $\in(\nu)$ distributes all over the conical train. After its radius grows up to the maximum $R_{\max}$; its energy $\in(\nu)$ begins to be restricted in a cylindrical lateral membrane that possesses charges $\pm e$. They form a stable structure of definite shape like a "solid" particle. We name it as $\in$-(energy) packet. Outside of it is the conical ψ-electromagnetic wave the packet closely connected. **An elementary train is consisted of $\in$ -(energy) packet and ψ - wave.** This is **the eighth very important feature** of it.

We will prove at once that for visible light, $R_{\max}$ is almost $10^{-7}\,m$. The $\in$-packet include its lateral membrane is often smaller than the width of a slit or a hole it will pass in the experiments. Existence of the interference patterns of multiple slits shows the pattern is just "superposed and formed" (self interference) by the ψ-wave. In other words, it is the ψ-wave forms the diffraction pattern around the obstacle to manage the behavior of the $\in$-energy packets. This pattern decides and describes the probability distribution of the $\in$-packet(s) **despite of which slit (hole) it passes**. The $\in$-packet is just a spot locates randomly on the front of the pattern during diffraction just like the dice(s). The ψ-wave is really the so-called probability wave of the $\in$-packet(s).

In a word**, it is the ψ-wave decides and describes the probability distribution of the $\in$-packet(s).** This is **the ninth important feature** of the elementary train(s).

Of course, if two elementary trains of same ν meet in the space they will be mutual interference as long as they possess enough coherent length.

Combine this wave property with particle property (Eq. (7)), we have proved the elementary train itself naturally possesses the wave particle duality. **It is such structure of $\in$-packet and ψ-wave unifies the particle-like and wave-like property of the electromagnetic radiation.** This structure gives us a visualized figure for duality. Einstein would certainly like to see it**.**[5]

Let's now turn to compute the energy of the $\in$-packet. In order to avoid complicate symbols operation we assume the train very slim so as the element of surface area $d\sigma_r$ on the wave surfaces can be simplified as $d\sigma_r = 2\pi\rho^2 \sin\varphi\, d\varphi \approx 2\pi\, r\, dr$. According to Eq. (10), the energy $\in = \in(\nu)$ of the $\in$-packet can be written as

$$\in(\nu) = \in = \frac{1}{2}\int_{\rho_0 - L}^{\rho_0} d\rho \int_{r=0}^{R} \varepsilon_0 \frac{A^2(\frac{r}{R})}{\rho^2} \nu^4\, 2\pi\, r\, dr \qquad (10)^*$$

Since Ω and $\Phi = \dfrac{R}{\rho}$ are invariant during propagation, we have

$$\in = \frac{1}{2}\int_{\rho_0 - L}^{\rho_0} d\rho \int_{\varphi=0}^{\Phi} \varepsilon_0 A_R^2 \Phi \nu^4\, 2\pi\, d\varphi = \pi\varepsilon_0 A_R^2\, \Phi^2 \nu^4 L$$

$$(R \le R_{\max}\, , \Phi = \frac{R}{\rho} = \frac{R_{\max}}{\rho_0}) \qquad (17)$$

Here ρ_0 is the distance between the point source and the end of the elementary train when it just becomes totally cylindrical.

On the other hand, after $\in$-packet becomes cylindrical we have $A^2(\frac{r}{R}) = A_R^2 \frac{R_{\max}}{r}$. Its energy can be written as

$$\in = \frac{1}{2}\int_{\rho_0}^{\rho_0+L} d\rho \int_{r=0}^{R_{\max}} \varepsilon_0 A_R^2 R_{\max} \nu^4 \, 2\pi \, dr = \pi\varepsilon_0 A_R^2 \, R_{\max}^2 \nu^4 L$$

(18)

Since $\Phi = \frac{R_{\max}}{\rho_0}$ and Eq. (17) and (18) must be equal, it gives $\rho_0 = 1m.$ for any ν .So **any elementary train of different frequencies possesses same time**

$$t_0 = \frac{\rho_0}{c} = \frac{1}{c}\sec \qquad (19)$$

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

According to Einstein, $dm = \frac{d\in}{c^2}$, the $\in$-packet's moment of inertia

$$\text{i}\, I = \frac{1}{2} L \int_{r=0}^{R_{\max}} r^2 \frac{\varepsilon_0}{c^2} A_R^2 R_{\max} \nu^4 \, 2\pi \, dr = \pi\varepsilon_0 A_R^2 R_{\max}^4 \nu^4 \frac{L}{3c^2} = \frac{\in R_{\max}^2}{3c^2} \qquad (20)$$

On the other hand, during a beam of circular polarized light is incident on an absorbing surface, classical electromagnetic theory predicts that the surface must experience a torque. [12][13] The magnitude $\Im$ of the torque per unit area is

$$\Im = \frac{J}{2\pi\nu} \qquad (21)$$

Irradiance J of the beam is the power per unit area.

Since the electromagnetic energy are quantized as we proved above, the beam of circular polarized light is consisted of the elementary trains. Let N be the number of the elementary trains per unit area that hit the surface every second, then we have $J = N \in (\nu)$ On the other hand, since $\Im = N\Theta$, they give $\Theta = \frac{\in}{2\pi\nu}$. Here Θ is the spin of an elementary train. According to the definition, the spin of an elementary train is $\Theta = 2\pi\nu I$, So

$$\Theta = 2\pi\nu I = \frac{\in}{2\pi\nu} \qquad (22)$$

Eq. (20) and (22) give

$$R_{\max} = \frac{\sqrt{3}\,c}{2\pi\nu} = \frac{\sqrt{3}}{2\pi}\lambda \qquad (23)$$

For visible light, if we take $\lambda = 6\times10^{-7}m$, then $R_{\max}$ is almost $1.7\times10^{-7}m$ and $\Phi = \frac{R_{\max}}{\rho_0} = 1.7\times10^{-7}rad$. The energy packet is very small and above assumption $d\sigma_r \approx 2\pi r\,dr$ is available.

Substitute Eq. (9) and $q = e$ into Eq. (15) and (17), we have

$$L = \frac{4\sqrt{3}\ c\, e\rho_0}{9M_0\nu} \qquad (\rho_0 = 1m) \qquad (24)$$

$$\in = \in(\nu) = h\nu \qquad (25)$$

Where

$$h = \frac{3\sqrt{3}\pi\, e\, M_0}{16\,\varepsilon_0 c\rho_0} \qquad (\rho_0 = 1m) \qquad (26)$$

Like the constant A_R and M_0, Eq. (9), h is a constant disregard of ν. It must be the famous Planck constant. [14] [15]

The $\in$ -packet possesses energy $\in = h\nu$. This is the eleventh feature of the elementary train**..**

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

On the other hand, Eq. (22) and (25) give the spin of the elementary train: [19]

$$\Theta = \hbar \qquad (\hbar = \frac{h}{2\pi}) \qquad (27)$$

The **spin** of the elementary train is **always equals to constant** $\hbar$ disregard of ν**.** This is **the twelfth important feature** of the elementary train. Spin's direction $\pm$ is decided by the direction of helical distribution of the train's **E**-field, right or left.

Use Planck constant h rewrite M_0, A_R and L as

$$M_0 = \frac{16\sqrt{3}\,\varepsilon_0 c\rho_0}{9\pi\, e} h \qquad (\rho_0 = 1m) \qquad (28)$$

$$A_R = \frac{4\sqrt{3}\ \rho_0}{3ec} h \qquad (29)$$

$$L = \frac{\pi\, e^2}{4\varepsilon_0 h\nu} \qquad (30)$$

Take Eq. (23) into account, we have the ratio

$$\frac{L}{R_{\max}} = \frac{\sqrt{3}\pi^2\, e^2}{6c\varepsilon_0 h} \approx 0.04 \qquad (31)$$

It holds for any frequency ν. It means $\in$ **-(energy) packets of different frequencies (different energy** $h\nu$ **) have different surface radius** $R_{\max}=\sqrt{3}\,c/2\pi\nu$ **but same shape and same ratio** $L/R_{\max}\approx 0.04$ like a circular coin. This is **the thirteenth feature** of the elementary train**.**

$\in$ -packet possesses energy $\in = h\nu$, definite shape and size $\pi R_{\max}^2 L\approx 0.04\pi R_{\max}^3$ and particle like property, it can be treated as a particle. Einstein relativistic relations[17] $\in^2 = p^2c^2+m_0^2c^4$ and $m_0=0$ give $p=h/\lambda$. The $\in$ **-packet possesses momentum** $p=h/\lambda$ is the **fourteenth important feature of the elementary train.**

The classical formula of total power P emitted by a vibrating electric dipole of moment $\mathrm{M}=\mathrm{M}_0\cos\varpi t$ is . $P=\dfrac{16\pi^3\mathrm{M}_0^2\nu^4}{3\varepsilon_0c^3}$.[6][13] Since Eq. (26), $P=\dfrac{16\pi^3\mathrm{M}_0^2\nu^4}{3\varepsilon_0c^3}=(\dfrac{256\sqrt{3}\,\pi^2\,\rho_0\mathrm{M}_0^2}{27c^2eM_0}\nu^3)h\nu$ and $\pi R_{\max}^2L=\dfrac{\sqrt{3}\,ec^3\rho_0}{3\pi M_0\nu^3}$, then we have

$$P=\frac{16\pi^3\mathrm{M}_0^2\nu^4}{3\varepsilon_0c^3}=(\frac{256\sqrt{3}\,\pi^2\rho_0\,\mathrm{M}_0^2}{27c^2eM_0}\nu^3)h\nu$$

$$=(\frac{256\,\pi\,c\,\rho_0^2\mathrm{M}_0^2}{27M_0^2}\frac{1}{\pi R_{\max}^2L})h\nu=Nh\nu \qquad (32)$$

$\dfrac{256\,\pi\,c\,\rho_0^2\,\mathrm{M}_0^2}{27M_0^2}$ has dimension (L^3T^{-1}). A train's volume $\pi R_{\max}^2L\propto\nu^{-3}$ has dimension (L^3). So N is the number of the elementary trains radiated every second. The bigger of ν, the smaller of train's volume ($\propto\nu^{-3}$) it makes N bigger and proportion to ν^3 ..

The difficulty in explaining the relation between the radiative power $P\propto\nu^4$ and the elementary train's energy $\in\propto\nu$ is no longer existed. It can be explained that the source radiates $N\propto\nu^3$ elementary trains every second and each train has energy $\in = h\nu$, so its radiative power is $P=N\in = Nh\nu\propto\nu^4$.

For fixed ν the function of right circularly polarized conical ψ -wave can be expressed as

$$E_x(x,y,z,t)=\frac{E(r)}{z}\cos 2\pi(\frac{z}{\lambda}-\nu t)$$

$$E_y(x,y,z,t)=\frac{E(r)}{z}\sin 2\pi(\frac{z}{\lambda}-\nu t)$$

$$(\ r=\sqrt{x^2+y^2}\prec R_{\max}\ ) \qquad (33)$$

It can be combined in complex form $E=E_x+iE_y$

$$\psi_+=E_+(x,y,z,t)=\frac{E(\sqrt{x^2+y^2})}{z}e^{-2\pi i(\nu t-\frac{z}{\lambda})} \qquad (34)$$

Helical distribution of field plus light speed make a definite frequency ν that the $\in$ **-packet** and ψ -wave rotate on the O-planes. It also decides the definite energy $\in = h\nu$, momentum $p = h/\lambda$ and the spin of the $\in$ **-packet**. Their magnitudes are necessary and sufficient condition to each other.

As for the left circularly polarized ψ **-wave** its function is

$$\psi_- = E_-(x, y, z, t) = \frac{E(\sqrt{x^2 + y^2})}{z} e^{2\pi i(\nu t - \frac{z}{\lambda})} \quad (35)$$

Similar to the way we used to introduce the Schrödinger equation[20] [21] [22] for the particles, take derivatives $\frac{\partial^2 \psi}{\partial t^2}$ and $\nabla^2 \psi$ from Eq. (34), (35), plus the relation $\in = h\nu$, $p = h/\lambda$ and $\in^2 = m_0^2 c^4 + p^2 c^2$, $m_0 = 0$ for the elementary train; it leads to the following Schrödinger equation despite of their different directions of polarization

$$\nabla^2 E = \frac{1}{c^2} \frac{\partial^2 E}{\partial t^2} \quad (36)$$

So the Maxwell equation is also the Schrödinger equation for the combination of $\in$ **-packet(s) and** ψ **-wave.**

Both $\in$ -**packet(s) and photon(s) possess same intrinsic properties: energy** $\in = h\nu$ **, momentum** $p = \in / c = h/\lambda$ **, spin** $\hbar$ **, duality and same forms of Schrödinger (Maxwell) equation.** Can we say they are equivalent? Can we say elementary train is really the photon? Or vice versa, the photon is really an elementary train. Or at least, the "equivalent photon". **This equivalence is the fifteenth important feature** of the elementary train.

Compare Eq. (10) and (17), we have

$$\frac{d\in}{d\rho} = \frac{\in}{L} = \pi \varepsilon_0 \nu^4 A_R^2 \Phi^2 = \varsigma(\nu) \quad (37)$$

For a specific ν , $\nu^4 A_R^2 \Phi^2$ and $\in / L$ is constant. It means if a ν **-train possesses more energy** $n\in = nh\nu$ **, it must have a longer train (coherent) length** nL **, not bigger cross sections.** This is **the sixteenth feature** of the elementary trains.

Since $h\nu$ and $nh\nu$ ($n \geq 2$) trains have same $R_{\max}$, so for a specific ν the slimmest symmetrical train that can exist in reality is the trains with angle $\Phi = R_{\max} / \rho_0 = \sqrt{3}\, c / 2\pi \rho_0 \nu$. Because the charge q in the train's membrane will be smaller than e , if its angle $\Phi \prec R_{\max} / \rho_0$. It is impossible.

Any general light beam is consisted of a bunch of the elementary trains. Its boundary is the common tangential surface of them, so $E = H = 0$ also hold. This common tangential surface is not an independent membrane, can not prevent the light beam from spreading out and form diffraction pattern like Airy disk. Spreading is owing to mutual interference of all ψ -waves inside the bunch.

At last let us discuss the possible mechanism: how an electron in the atom absorbs a photon. We used to think the photon must be dimensionless otherwise how an almost dimensionless electron can absorb it up? But absorption need not eaten up, it may happen in another way. In fact, during a $h\nu$ -train pumps an electron, squeezed of the train's electric field greatly increases the maximum stress $\Sigma_{\max} \propto E^2$ in the membrane and split it along double helix; release of potential energy will shrink the pair of semicircular $\pm$ charged membranes into a pair of spiral tapes with charge $\pm$. Owing to electric induction, the outer surface of the electron will produce a pair of $\mp$ charged spirals. The inner $\mp$ pair will carry the outer $\pm$ pair to move together and shrinks the diameter of the outer until "being wrapped". It forms a moving "new electron" from lower energy level $h\nu_1$ jump to the higher lever $h\nu_2$ $(\nu_2 = \nu_1 + \nu)$ and possesses different sign $\pm$ of spin $\hbar/2$.[11] Electron of $\pm\hbar/2$ can only absorb the photon with spin $\mp\hbar$ respectively, because electron can not have a spin differed from $\hbar/2$.

Once the outer spirals have to leave the electron

the extremely small $\mp$ charged spirals will become a rotating electric dipole on the O-plane to excite and transfer itself to a new conical train with same ν to radiate. And the electron backs to its original state.

III. About the external production of the $\pm$ leptons and $\pm$ hadrons. And mass distribution in the particles produced.

If the energy of a photon satisfies $\succ 2mc^2$ and have a collision with heavy nucleus, the experiments show a pair of particles like ±electron etc. may be produced.

Energy transferring to material is easy to understand; but why not produces a pair of uncharged particles but charged ones? Where do the charge $\pm e$ come from? If it is from nothingness in the space, why just $\pm e$ not 0 or $\pm 2e$, $\pm 3e$?

On the contrary, it is a natural process and easy to understand if $\pm e$ are split from the elementary train. Besides, if the particles produced from pair production are split from an elementary train the conservation of spin inspires us both photon and particles are very likely having similar mechanism to make their spin. In other words, we can predict the particles produced may have spiral structure of mass that are transferred point to point directly from the elementary train's energy. Our next paper will discuss it and show many interesting results.

We now try to give a brief discussion about the pair production. If the energy of a photon is $\succ 2mc^2$ and having collision with a heavy nucleus, deceleration will squeeze the train's field **E** and makes

$\Sigma_{\max} \propto A_R^2$, Eq. (13) over load to break the membrane along A-spiral and F-spiral. The photon will split into a pair of independent ±charged spiral-halves (no longer a photon but two independent unformed particles with ±charges e.

For the first stage: After the split along A-spiral and F-spiral in the membrane, the change of the two parts are similar. For each part, in consideration of symmetry, release of potential energy will make (i) the circular membranes in all cross sections shrink into linear diameters; (ii) the electric repulsion will bisect every dq into $2\times\frac{dq}{2}$ and locate at their end points A and F respectively. The charge distributes in double helix; (iii) in the mean time, the symmetry of the charge distribution on any cross section will make the energy distributes symmetrically about X-axis (diameter $\overline{AF}$) and Y-axis of the section.

The energy density inside each unformed particle distributes spirally and have same pitch as the charge q .

Translational motion along z-axis makes the different sign of charged spirals rotating on same O-planes to produce different direction of magnetic fields. It will cause the two small unformed particles separated.

At the end of the first stage separation just complete but still at speed c ,conservation laws make each unformed particle had spin $\hbar/2$ and

$$\in=\frac{1}{2}h\nu_\gamma \overset{let}{=} h\nu \qquad (38)$$

$$\nu_\gamma\lambda_\gamma = c = \nu\,\lambda_c \qquad (39)$$

Or

$$\nu = \frac{1}{2}\nu_\gamma \qquad (40)$$

$$\lambda_c = 2\lambda_\gamma \qquad (41)$$

Where $\nu\,(=\frac{1}{2}\nu_\gamma)$ is the instinct frequency of the (unformed) particle it guarantees its spin $\hbar/2$. $\lambda_c\,(=2\lambda_\gamma)$ represents the pitch of the (unformed) particle at speed c. This elongation must be owing to the repulsion between same sign of spiral charges in each part.

The second stage: at last, the energy of the unformed particle transfer to the mass; its speed decreases to $V(\prec c)$ and becomes a formed particle.

The electromagnetic energy density $E^2 = E_R^2 \frac{R}{r}$, Eq. (7)* will transfer to the mass density $\sigma = \sigma_R \frac{R}{r}$ on any cross section with thickness dr. Spiral distribution of electromagnetic energy will transfer to spiral distribution of mass. Then, the cohesion between particle's material will appear and concentrate the distribution of mass density around the center. It gives

$$\sigma = \sigma_R (\frac{R}{r})^\kappa \qquad (1 \le \kappa \prec 2). \qquad (42)$$

if the particles keep the cylindrical shape. Here $\kappa = 1$ means the particles have same density distribution as the photon; Since the integral $m = \int_0^R 2\pi r \sigma dr$ is divergent if $\kappa \ge 2$, it should be excluded. So $1 \le \kappa \prec 2$. Eq. (42) means the mass density of the particles around the center may bigger than the photon. Unknown coefficient κ relates to the law of cohesion.

On the other hand, conservation laws make the energy ν and spin $\hbar/2$ unchanged. Only change happens to its pitch. According to the special relativity, its momentum p is

$$p = mV = \frac{h\nu}{c^2} V \overset{(25)}{=} \frac{h}{\lambda_c} \frac{V}{c} \overset{let}{=} \frac{h}{\lambda_V}. \qquad (43)$$

or

$$p = \frac{h}{\lambda_V} \qquad (\lambda_V = \frac{c}{V} \lambda_c = \frac{c^2}{V} T_c) \qquad (44)$$

Formed particle's pitch λ_V is $\frac{c}{V}$ times of the unformed particle λ_c. This lengthening effect is owing to the appearance of none zero rest mass. In fact, Einstein's energy- -momentum relation gives $p^2 = \frac{\in^2}{c^2} - m_0^2 c^2 \overset{(33)}{=} \frac{h^2 \nu^2}{c^2} - m_0^2 c^2$, $\frac{h^2}{\lambda_V^2} = \frac{h^2}{\lambda_c^2} - m_0^2 c^2$. The appearance of the term $m_0 \ne 0$ increases its pitch from λ_c to λ_V.

Under this elongation effect, the length L of the particles will become far bigger than $0.04R$ if it keeps cylindrical, because $c/V \succ\succ 1$ in general.

According to above discussion, we can expect theoretically that other $\pm$ leptons and $\pm$ hadrons will be produced in pair production if they satisfy same conditions: the energy of a photon satisfies

$\succ 2mc^2$ and have a collision with heavy nucleus or other similar conditions.

We have noticed that the relations $\in = h\nu$, Eq. (38) and $p = h/\lambda_V$ of $\pm$ charged particles are just a logical result from the study of pair production. They reflect the wave features owing to the particle's helical structure of mass.

$\pm$ Charged particles and photon possess same form of equations $\in = h\nu$ and $p = h/\lambda_V$ is because of they all possess similar helix structure: the distribution of mass and (field) energy respectively.

It is evident that from any inertial system to investigate the pair production they will have same form of Eq. (38) and (44). They as the components of four-vector are Lorentz covariant.

The problem where the charges $\pm e$ come from in the pair production can be well explained if the photon is an elementary train.

IV. The existence of longer $nh\nu-$train.

We now use "train" concept to study Einstein theory about spontaneous and stimulated emission.

The decrease of atom populations for spontaneous radiation from energy level 2 to level 1 is

$$dN_2 = -AN_2 dt \tag{45}$$

A represents transition probability. Then

$$N_2 = N_{20} e^{-At} \tag{46}$$

Average lifetime τ_{spon} is

$$\tau_{spon} = \frac{1}{N_{20}} \int_0^{N_{20}} t\ dN_2 = \frac{1}{A} \tag{47}$$

Time gap between any two successive photons radiated from an atom may exist; τ_{spon} is not the real average lasted time $\tau_0 = \frac{L}{c}$ to radiate a $h\nu$-photon train. So $\tau_0 = j\tau_{spon}$, $j \prec 1$.

Quantization of charge makes all spontaneous photon trains from energy level 2 to level 1 must have same radiative time τ_0 and same train length $L = c\tau_0$.

According to Fourier analysis, the width of natural spectral line $\Delta\nu$ is a measure of the time τ_{spon}. $\tau_{spon}\ \Delta\nu \geq 1$; As well as it must be also a measure of the time $\tau_0 = j\tau_{spon}$: Then

$$\tau_0\ \Delta\nu \geq 1 \tag{48}$$

On the other hand, $\Delta\nu$ is correspondent to the natural width of energy level 2 $\Delta\in(=h\,\Delta\nu)$ ($\nu+\Delta\nu=\frac{\in_2-\in_1+\Delta\in}{h}$). So, we have $\tau_0\ \Delta\in\geq h$ or $\Delta\in\geq h\,A$, A (τ_0 also)

is a measure of the natural width of energy level 2 in the case of spontaneous emission.

For stimulated emission, the number of downward transitions in dt is

$$dN_2=-Bu_\nu N_2\,dt \qquad (49)$$

In compare with τ_{spon} , there is no reason to prevent us to introduce the idea of average stimulated radiative lifetime of N_{20} . That is

$$\tau_{stim}=\frac{1}{N_{20}}\int_0^{N_{20}}t\,dN_2=\frac{1}{Bu_\nu} \qquad (50)$$

According to the sixteenth feature of $h\nu$-train, the energy per train length, Eq. (37) is a function of single variable ν

$$\frac{d\in}{d\rho}=\frac{\in}{L}=\pi\,\varepsilon_0\nu^4A_R^2\,\Phi^2=\varsigma(\nu) \qquad (51)$$

It is constant for fixed ν. Take eq. (47) and (50) into account, it give us $\frac{\in_{simu}}{\in_{spon}}=\frac{L_{simu}}{L_{spon}}=\frac{\tau_{simu}}{\tau_{spon}}=\frac{A}{Bu_\nu}$. For natural light source and visible ray, the well known relation gives

$$\frac{\in_{stim}}{\in_{spon}}=\frac{\tau_{stim}}{\tau_{spon}}=\frac{A}{Bu_\nu}=(e^{\frac{h\nu}{kT}}-1)\succ\succ 1 \qquad (52)$$

The average energy of the stimulated photon trains is far greater than the spontaneous one. Two kinds of trains have same ν but different energies. Where does the extra energy $(n-1)h\nu$, ($n=2,3,...N(\succ K)$) come from? Or where does the extra energy storage before radiation?

Similar to A, Bu_ν is a measure of the width of energy level 2 in the case of stimulated emission. $Bu_\nu\prec\prec A$ refers to that the average width of energy level 2 in case of stimulated emission is far smaller than the one of spontaneous emission. **Extra energy must be stored by means of the compression of the width of energy level 2. Energy levels of different width deposit different amount of energies. They spend different time $\tau_{stim}=\frac{1}{Bu_\nu}$ to radiate different length $L=c\,\tau_{stim}$ of trains with different energies.**

Average energy $Kh\nu$ of stimulated photon trains refers to that trains emitted from level E_2 may possess energy $2h\nu$, and $3h\nu$, and …, $nh\nu\,(n \succ K)$. They are radiated from the energy levels E_2 of different width. After radiation of a **longer train** with energy $nh\nu$ $(n = 2,3,...)$, the electron falls down to E_1 from E_2..

Equation (45) and (46) are also available for level 1 by replaced subscript 2 to 1. Level 1 and 2 have same average stimulated radiative lifetime. It refers to that electrons at level 1 can accept the train $\in_{stim} = h\nu$ or $2h\nu$, or $3h\nu$, or…, directly (or even accumulate them) from radiation field to compress energy level and then jump back to level 2 with energy $nh\nu$ $(n = 2,3,...)$. Electromagnetic field in equilibrium is consisted of $nh\nu$ -packets $(n = 1,2,3,...)$, the state of n photons with energy $nh\nu$; and steady distribution of their $2\pi n\nu$ ψ -waves (Fourier modes).

Now let us consider the spin condition of the electron in the process of emission and absorption, It will give us further results. Because an electron can not have a spin differed from $\pm\frac{\hbar}{2}$, so if the spin of ν_1- electron at level 1 is $+\frac{\hbar}{2}$ (or $-\frac{\hbar}{2}$**)**, it can only except a $h\nu-$photon with different sign of spin $\hbar$ and becomes an ν_2-electron jumps to level 2 with spin $-\frac{\hbar}{2}$ (or $+\frac{\hbar}{2}$)**;** if then, the electron continuously except another $h\nu-$train at level 2 to compress the width of energy level, the next photon must be of different direction of polarization so as to make electron spin back to original $+\frac{\hbar}{2}$ (or $-\frac{\hbar}{2}$**)**. This is to say the two continuous $h\nu-$trains absorbed must be in different direction of circular polarized. Their total spins ($+h\langle plus\rangle - h$ or $-h\langle plus\rangle + h$) is zero. If energy level 2 no longer accepts another photon but radiates, what we can assert for the next radiation from level 2 is a $2h\nu$-packet carried by the linear polarized $\psi-$wave. **This combination is a linear polarized $2h\nu-$packet carried by a linear polarized** $\psi-$wave**.** We call it as **couple train** for convenience**.** It may have two kinds of order ($+h\langle plus\rangle - h$) or ($-h\langle plus\rangle + h$) but zero spin.

Since the existence of couple train(s), the electron can accept it to compress the width of energy level directly without spin restriction.

So in the cavity of thermal equilibrium, although single photon is circular polarized, spin condition of electron gives us the conclusion: **higher energy level 2 of the matter may radiate $(2n+1)h\nu-$ trains (**$n = 0,1,...$**) with different sign of spin** $\hbar$ **and $2nh\nu-$trains (**$n = 1,2,...$**) of linear polarization with different order of couple trains,** ($+h\langle plus\rangle - h$) or ($-h\langle plus\rangle + h$). The electrons in lower level 1 may absorb any of them to jump to level 2..

Especially for the radiation from the vibrating electric dipole, the accelerated charge and the antenna, symmetry always demands their radiations to be linear polarized. Now we can say they can be consisted of linear polarized $2nh\nu-$trains ($n=1,2,...$).

Since the $\psi-$waves of $2nh\nu-$packet ($n=1,2,...$) are understood to be included E-components and H-components and satisfy correspondent boundary conditions so all the discussions about the linear polarized light in classical electromagnetic theory must be available to them.

It is evident, if photon's probability wave is not electromagnetic original, without two perpendicular E- and H- components, it will fail to use above macroscopic laws. This is also a reason that above $\psi-$ **w**aves from Maxwell theory must be the probability wave of the photon(s).

It seems the Laser is the trains of very long coherent length. We will have a further paper to discuss the existence of the $nh\nu$ -trains.

At last we discuss the possible mechanism: how an electron absorbs a photon. We often think photon must be dimensionless otherwise how a dimensionless electron can "eat" it up? In fact, absorption may happen in another way. During a $h\nu$-train pumps an electron, squeeze of electric field greatly increases the maximum stress $\Sigma_{\max}\propto A_R^2$, eq. (13) in the membrane and split it along the helix; release of potential energy will shrink the pair of semicircular $\pm$charged membranes into a pair of $\pm$charges spirals. Owing to electric induction, the inner surface of electron will produce a pair of $\mp$ charged spirals. The latter pair will carry the outer pair to move together and shrinks the diameter of outer pair until "being wrapped". It forms a moving "new electron" from lower energy level $h\nu_1$ jump to higher lever $h\nu_2$ with different direction of spin ($+\frac{\hbar}{2}\to-\frac{\hbar}{2}$ or $-\frac{\hbar}{2}\to-+\frac{\hbar}{2}$). Once the outer spirals have to leave the electron, the extremely small $\pm$charged spirals will become a rotating electric dipole on the O-plane to excite and transfer itself to a new conical train with same ν to radiate.

It seems the Laser is the trains of very long coherent length. We will have a further paper to discuss the existence of the $nh\nu$ -trains.

Since $h\nu$ and $nh\nu$ ($n\geq 2$) trains have same $R_{\max}$, so for a specific ν the slimmest symmetrical train that can exist in reality is the trains with angle $\Phi=R_{\max}/\rho_0=\sqrt{3}\,c/2\pi\rho_0\nu$. Because the charge q in the train's membrane will be smaller than e, if its angle $\Phi\prec R_{\max}/\rho_0$. It is impossible.

V. Conclusion

Photon as used to know is an elementary particle with electromagnetic energy $h\nu$. Can we ask ourselves why the photons have the ability to reject the influences from external electromagnetic field to keep unchanged through deep universe for more than ten billion years? Is it consisted of material ($m_0 = 0$) or its energy and structure is protected by such material shell as a screen? So the existence of the lateral membrane of the elementary train is of no surprise.

On the basic of Maxwell theory and the principle of charges quantization, we proved that for any specific ν, a slim symmetrical electromagnetic wave beam of minimum energy is a wave train of length L and covered by a lateral membrane of special material $m_0 = 0$. The train possesses basic characters as the photon: $\in = h\nu$, $p = h/\lambda$, spin $\hbar$, duality and satisfies the Maxwell (Schrodinger) equation. We have good reasons to think that photon of any definite frequency ν is a slim symmetrical electromagnetic wave beam of minimum energy (relative to same ν) it possesses above sixteen important features.

This photon train is consisted of $\in$-(energy) packet and ψ-(electromagnetic) wave. $\in$-packet is a circular polarized electromagnetic field wrapped by a cylindrical lateral membrane with charge $\pm e$ The equilibrium between the inner field and $\pm$ charges in the membrane forms an extremely stable entity. It can bring the packet unchanged from the deep universe to us. The $\in$-packets of different energies have different radius $R_{\max} = \sqrt{3}\, c / 2\pi\nu$ but same shape with same ratio $L / R_{\max} \approx 0.04$ like a circular coin. $\in$-packet floats on and is carried by the ψ-wave to move together. The electromagnetic ψ-wave decides and describes the probability behavior of the $\in$-packet(s). It is such structure, $\in$-packet plus ψ-wave unifies the duality of a photon.

The particles produced or can be produced theoretically from the pair production possess spiral structure of mass similar to the distribution of **E,H** in the photons. The distribution of mass density on the particles' cross sections satisfy $\sigma = \sigma_R (\frac{R}{r})^{\kappa}$ if the particles keep cylindrical shape unchanged.

All these result are derived and calculated from the Maxwell theory itself. It shows perfectly the consistency and capacity of the Maxwell theory.

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