The photon model and equations are derived through time-domain mutual energy current

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Abstract: In this article the authors will build the model of photon in time-domain. Since photon is a very short time wave, the authors need to build it in the time domain. In this photon model, there is an emitter and an absorber. The emitter sends the retarded wave. The absorber sends advanced wave. Between the emitter and the absorber the mutual energy current is built through together with retarded wave and the advanced wave. The mutual energy current can transfer the photon energy from the emitter to the absorber and hence photon is nothing else but the mutual energy current. This energy transfer is built in 3D space, this allow the wave to go through any 3D structure for example the double slits. The authors have proven that in the empty space, the wave can be seen approximately as 1D wave without any wave function collapse. That is why the light can be seen as light line. That is why a photon can go through double slits to have the interference. The duality of photon can be explanted using this photon model. The total energy transfer can be divided as self-energy transfer and the mutual energy transfer. In authors photon model the wave carries the mutual energy current is never collapse. The part of self-energy part has no contribution to the energy transferring. The self-energy items is cancelled by the advanced wave of the emitter current and the retarded wave of the absorber current. Furthermore, the author found the photon should satisfy the Maxwell equations in microcosm. Energy is transferred only by the mutual energy current. In this solution, the two items in the mutual energy current can just interpret the line or circle polarization or spin of the photon. The concept of wave function collapse is avoided in the authors' photon model.

Keyword: Photon, Quantum, Advanced wave, Retarded wave, Poynting theorem, Mutual energy, Maxwell equation.

1. Introduction

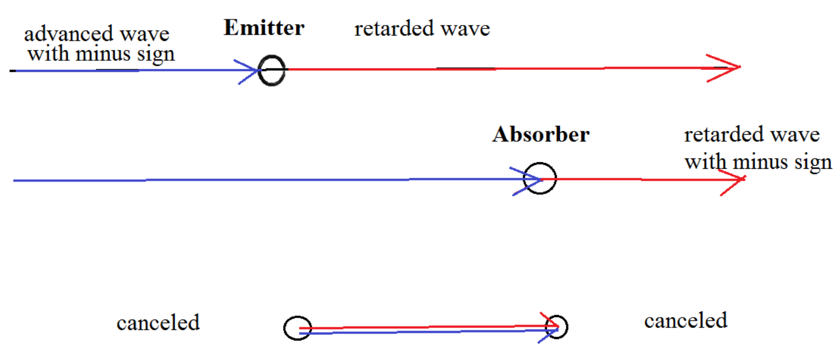
The Maxwell equations have two solutions one is retarded wave, another is advanced wave. Traditional electromagnetic theory thinks there is only retarded waves. The absorber theory of Wheeler and Feynman in 1945 offers a photon model which contains an emitter and an absorber. Both the emitter and the absorber sends half retarded and half advanced wave [1,2]. J. Crammer built the transactional interpretation for quantum mechanics by applied the absorber theory [3,4,5] in 1986. In 1978 Wheeler introduced the delayed choice experiment, which strongly implies the existence of the advanced wave [6]. The delayed choice experiment is further developed to the delayed choice quantum eraser experiment [7], and quantum entanglement ghost image and the ghost image clearly offers the advanced wave picture [8]. The first author of this article has introduced the mutual energy theory in 1987 [9-11]. Later he noticed that in the mutual energy theory the receive antenna sends advanced wave [12] and begin to apply it to the study of the photon and the other quantum particles [13,14]. The above studies are all in Fourier domain which is more suitable to the case of the continual waves. The authors know photon is very short time waves, hence decided to study it in the time-domain instead of Fourier domain.

The goal of this article is to build a model for photon, find the equations of the photon. Some one perhaps will argue that photon is electromagnetic field it should satisfy Maxwell equations, or photo is a particle it should satisfy Schrodinger equations, why to find other equations? First we are looking vector equations which photon should satisfy. These equations cannot be Schrodinger equation. Second we know that infinite more photons become light or electromagnetic field which should satisfy Maxwell equations. Hence Maxwell equations are a macrocosm field. In microcosm, only singular photon we are very difficult to think it still satisfies the Maxwell equations. Hence the singular photon, perhaps it satisfies Maxwell equation and perhaps it not. We try to find these equations for photon to satisfy, from which, if we add all equations for a lot of photons, we should obtain Maxwell equations.

2. The photon model of Wheeler and Feynman

In the photon model of Wheeler and Feynman there is the emitter and absorber which sends all a half retarded wave and half advanced wave. The wave is 1-D wave which is a plane wave send along $\mathbf{x}$ direction. Like wave transferred in a wave guide. For bother emitter and the absorber, the retarded wave is sent to the positive direction along the $\mathbf{x}$. The advanced wave is sent to the negative direction along $\mathbf{x}$. We take color red to draw the retarded waves. We take color blue to draw the advanced wave, see the Figure 0. For the retarded wave the arrow is drawn into the same direction of the wave. For the advanced wave the arrow in the opposite direction of the wave (since the energy transfers in the opposite direction for the advanced wave).

For the absorber, Wheeler and Feynman assume the retarded wave send by absorber is just negative (or having a 180 degree of phase difference) compare to the retarded wave send from the emitter. The advanced wave sent from the emitter is just negative (or 180 degree of phase difference) of the advanced wave sent by the absorber. See Figure 1. Hence, In the regions I and III, all the waves are canceled. In the region II the retarded wave from emitter and the advanced wave from absorber



reinforced.

Figure 0. The Wheeler and Feynman model. The emitter sends retarded wave to right shown as red arrow. The emitter sends advanced wave to the left which is blue. We have drawn the arrow in the opposite direction to the advanced wave. This is same to the absorber. However, the retarded wave of the absorber is just the negative value of the retarded wave (or it has 180 degree phase difference). The

advanced wave sent by the emitter is also with negative value of that of the absorber (or has 180 degree phase difference). Hence in the region I and III the waves are cancelled and in the region II the waves are reinforced.

All this model looks very good and it is very success in cosmography, but it is difficult to be believe. First

(a) Why the retarded wave is sent by the emitter to the positive direction and the advanced wave is sent to the negative direction? As we understand the wave should send to all directions, in 1-dimension situation should send to the positive direction and send to the negative direction.
(b) Why the absorber sends retarded wave just with a minus sign so it can cancel the retarded wave of the emitter? It is same to the Emitter, why it can send an advanced wave with minus sign so it just can cancel the advanced wave of the absorber?
(c) 1-D model is too simple. The wave is actually send to all direction and should check whether this model can be used also in 3D situation. What happens if this model for 3D?

These questions perhaps are the real reasons that Wheeler and Feynman theory and all the following theory for example the transactional interpretation of J. Crammer cannot be accept as a mainstream of photon model or the theory for interpretation of the quantum mechanics.

The authors endorse the absorber theory of Wheeler and Feynman. In this article we will introduce a 3D time-domain electromagnetic theory which suits to the advanced wave and retarded wave to replace the 1-D photon model of Wheeler and Feynman. In this new theory the mutual energy current will play an important role.

3. Poynting theorem

For a photon, all the energy has been received by one absorber. We do not know whether or not the photon can fully satisfy the Maxwell equations. Because according Maxwell equations the emitter will send their energy to whole space instead to only one point. However, we believe the equations of photon should be very close to Maxwell equations, that means even in the microcosm the Maxwell equations doesn't satisfied, but for the total field that means the field of infinite photons should still satisfy the Maxwell equations. The next step we begin to find the equations of the photon. We started from Maxwell equations, which implies that Poynting theorem is established. Hence we started from Poynting theorem to find the theory suit to photon.

(1)

$$-\oiint_{\Gamma} (\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma = \iiint_V (\boldsymbol{J}\cdot\boldsymbol{E}+\partial\boldsymbol{u})dV$$

Where $\boldsymbol{E}$ is the electric field. $\boldsymbol{H}$ is the magnetic H-field. $\boldsymbol{J}$ is the current intensity. Γ is the boundary surface of volume V. $\boldsymbol{u}$ is energy saved on the volume V. $\vec{\boldsymbol{n}}$ is unit norm vector of the surface Γ. $\boldsymbol{u}$ is the electromagnetic field energy intensity. ∂u is defined as

(2)

$$\partial u = \frac{\partial}{\partial t}u = \boldsymbol{E}\cdot\frac{\partial}{\partial t}\boldsymbol{D} + \boldsymbol{H}\cdot\frac{\partial}{\partial t}\boldsymbol{B}$$

Where $\boldsymbol{D} = \boldsymbol{\epsilon E}$ is the electric displacement, $\boldsymbol{B} = \boldsymbol{\mu B}$ is magnetic B-field. $\boldsymbol{\epsilon}, \boldsymbol{\mu}$ are permittivity and permeability. ∂u is the increase of the energy intensity. The above equation is Poynting theorem, which tell us the energy come through the surface to the inside the region $-\oiint_\Gamma (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma$ is equal to the energy loss $\iiint_V (\boldsymbol{J} \cdot \boldsymbol{E}) dV$ in the volume V and increase of the energy inside the volume V $\iiint_V (\partial \boldsymbol{u})\, dV$.

We assume the field as $\zeta = [\boldsymbol{E}, \boldsymbol{H}]$ is electromagnetic field, which can be a superimposed field with retarded wave and advanced wave. This means we assume the advanced wave and retarded wave can be superimposed. This is not self-explanatory, if we consider many people even do not accept advanced waves.

We have known form Poynting theorem we can derive all reciprocity theorems. We also know the Green function solution of Maxwell equations can be derived from reciprocity theorems. If we obtain all the solution of Maxwell equations, from principle we should be possible do obtained Maxwell equations by induction. Hence even we cannot derive Maxwell equation from Poynting theorem but we still can say that the Poynting theorem contains nearly all the information of the Maxwell equations. We can say that if some field satisfies Poynting theorem, it also satisfies Maxwell equations. This point of view will be applied in the following sections.

4. 3D photon model in the time-domain with mutual energy current

Assume the $\boldsymbol{i}$-th photon is sent by an emitter and received by an absorber. The current in the emitter can be written as $\boldsymbol{J_{1i}}$, the current in the absorber can be written as $\boldsymbol{J_{2i}}$. In the absorber theory of Wheeler and Feynman, the current is associated half retarded wave and half advanced wave. We don't take their choice in this moment, in the later of this article we will discuss this assumption. In this moment we take a very similar proposal. We assume the emitter $\boldsymbol{J}_{1i}$ is associated only to a retarded wave and the absorber $\boldsymbol{J_{2i}}$ is associated only to an advanced wave. The photon should be the energy current sends from emitter to the absorber. This proposal, is same as the picture of the bottom of Figure 0. It should be notice that in the following article there two kinds of filed, one it the photon's field which will have subscript $\boldsymbol{i}$, and this is microcosm field for example $\boldsymbol{J_{1i}}, \boldsymbol{E_{1i}}, \boldsymbol{H_{1i}}$. Another is the field without the subscript $\boldsymbol{i}$ which is the macrocosm field, for example $\boldsymbol{J_1}, \boldsymbol{E_1}$.

Assume the advanced wave is existent same as retarded wave. Assume the current can produced advanced wave and also retarded wave. In this case we always possible to divide the current as two parts, one part created advanced field and the other part created retarded wave. Assume $\boldsymbol{J_{1i}}$ produces retarded wave $\xi_{1i} = [\boldsymbol{E_{1i}}, \boldsymbol{H_{1i}}]$. $\boldsymbol{J}_{2\mathrm{i}}$ produces advanced wave $\xi_{2i} = [\boldsymbol{E_{2i}}, \boldsymbol{H_{2i}}]$.

Assume the total field is a superimposed field $\xi_i = \xi_{1i} + \xi_{2i}$, ξ_{1i} is retarded wave and ξ_{2i} is advanced wave. $\xi_{1i} = [\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$ which is produced by $\boldsymbol{J_{1i}}$ and $\xi_{2i} = [\boldsymbol{E}_{2i}, \boldsymbol{H}_{2i}]$ which is produced by $\boldsymbol{J_{2i}}$. Substitute $\xi_i = \xi_{1i} + \xi_{2i}$ and $\boldsymbol{J_i} = \boldsymbol{J}_{1i} + \boldsymbol{J}_{2i}$ to Eq.(1). From Eq.(1) subtract the following self-energy items,

(3)

$$-\oiint_\Gamma (\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\mathbf{J_{1i}} \cdot \boldsymbol{E_{1i}} + \partial u_{\boldsymbol{1i}}) dV$$

(4)

$$-\oiint_{\Gamma} (\boldsymbol{E}_{2i} \times \boldsymbol{H}_{2i}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_{V} (\mathrm{J}_{2i} \cdot \boldsymbol{E}_{2i} + \partial u_{2i})dV$$

which becomes

(5)

$$-\oiint_{\Gamma} (\boldsymbol{E}_{1i} \times \boldsymbol{H}_{2i} + \boldsymbol{E}_{2i} \times \boldsymbol{H}_{1i}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_{V} (\mathbf{J}_{1i} \cdot \boldsymbol{E}_{2i} + \mathbf{J}_{2i} \cdot \boldsymbol{E}_{1i})dV$$

$$+ \iiint_{V} (\boldsymbol{E}_{1i} \cdot \partial \boldsymbol{D}_{2i} + \boldsymbol{E}_{2i} \cdot \partial \boldsymbol{D}_{1i} + \boldsymbol{H}_{2i} \partial \boldsymbol{B}_{1i} + \boldsymbol{H}_{2i} \partial \boldsymbol{B}_{1i})dV$$

If we call Eq.(3 and 4) as self-energy items of Poynting theorem, the Poynting theorem Eq.(1) with $\xi = \xi_{1i} + \xi_{2i}$ are total field of the Poynting theorem. Then the above formula Eq.(5) can be seen as mutual energy items of Poynting theorem. It also can be referred as mutual energy theorem because it is so important which will be seen in the following sections.

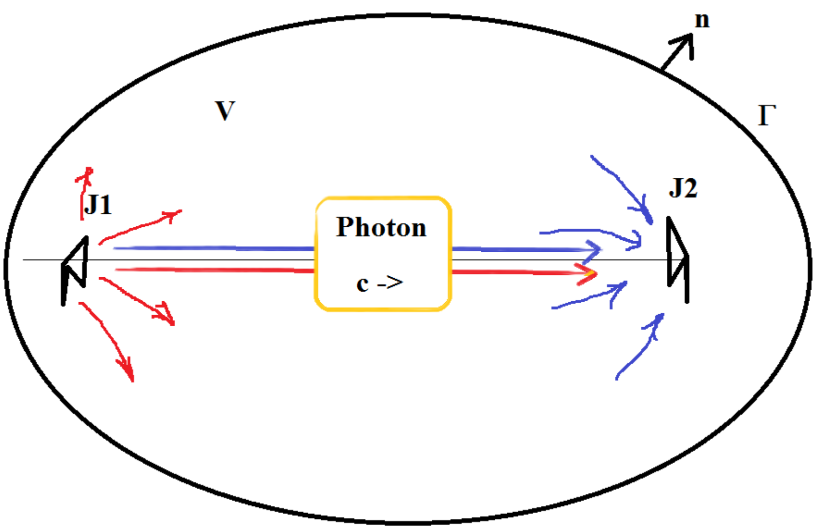


Figure 1. Photon model. There is an emitter and an absorber, emitter send retarded wave. The absorber sends advanced wave. The photon is sent out in $t = 0$, in short time Δt, hence photon is sent out from $t = 0$ to Δt, the photon has speed c. After a time T it travels to distance $R = cT$, where has an absorber. The figure shows in the time $t = \frac{1}{2}T$, the photon is at the middle between the emitter and the absorber. The length of the photon is $\Delta t * c$. The photon is showed with the yellow region.

Eq.(5) can be seen as the time domain mutual energy theorem. For photon, it is very small. The self-energy part of Poynting theorem Eq.(3-4) perhaps is no sense. This is because that the first part of self-energy it cannot be received by any other substance. It can hit some atom, but the atom has a very small section area, so the energy received by the atom is so small hence cannot produce a particle like a photon even with very long time. Because photon is a particle, all its energy should eventually be received by the only one absorber. This part energy current (the self-energy item) is diverged and sent to infinite empty space. Hence it ether does not existent or need to be collapsed in some time. This two possibility will be discussed later in this article. For the moment we just ignore these two self-energy items of Poynting energy current items. Assume all energy is transferred through the mutual energy current items.

We know that $\boldsymbol{\xi_{1i}} = [\boldsymbol{E_{1i}}, \boldsymbol{H_{1i}}]$ is retarded wave, $\boldsymbol{\xi_{2i}} = [\boldsymbol{E_{2i}}, \boldsymbol{H_{2i}}]$ is advanced wave. On the big sphere surface Γ, $\boldsymbol{\xi_{1i}}$ is no zero at a future time T_Γ to $T_\Gamma + \Delta t$. $T_\Gamma = R_\Gamma / c$, where c is light speed, R_Γ is the distance from the emitter to the big sphere surface. Δt is the life time of the photon (from it begin to emit to it stop to emit, in which $\boldsymbol{J_{1i}} \neq 0$). Assume the distance between the emitter and the absorber is d with $d \ll R$. $\boldsymbol{J_{2i}} \neq 0$, Is at time T to $\mathrm{T} + \Delta\mathrm{t}$, $\mathrm{T} \ll \mathrm{T}_\Gamma$. $\boldsymbol{\xi_{2i}}$ is an advanced wave and it is no zero at $-T_\Gamma$ to $-(T_\Gamma + \Delta t)$ on the surface Γ Hence the following integral vanishes ($\boldsymbol{\xi_{1i}}$ and $\boldsymbol{\xi_{2i}}$ are not nonzero in the same time, on the surface Γ). In the above calculation we have assume T is very small compared with T_Γ, hence we can write $T \to 0$. Hence we have,

(6)

$$-\oiint_\Gamma (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = 0$$

We notice that the above formula is very important, that means the mutual energy cannot be sent to the outside of our cosmos. The above formula is only established when the $\boldsymbol{\xi_1}$ and $\boldsymbol{\xi_2}$ are one is retarded wave and another is advanced wave. If they are same wave for example both are retarded waves the above formula is not established. This is also the reason we have to choose for our photon model as one is retarded wave and the other is advanced wave. Hence from Eq.(5) and (6) we have

(7)

$$-\iiint_V (\mathbf{J_{1i}} \cdot \boldsymbol{E_{2i}}) dV = \iiint_V (\mathbf{J_{2i}} \cdot \boldsymbol{E_{1i}}) dV$$
$$+ \iiint_V (\boldsymbol{E_{1i}} \cdot \partial \boldsymbol{D_{2i}} + \boldsymbol{E_{2i}} \cdot \partial \boldsymbol{D_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}}) dV$$

The left side of Eq.(7) is the sucked energy by advanced wave $\boldsymbol{E_{2i}}$ from $\boldsymbol{J_{1i}}$, which is the emitted energy of the emitter. $\iiint_V (\mathbf{J_{2i}} \cdot \boldsymbol{E_{1i}}) dV$ is the retarded wave $\boldsymbol{E_{1i}}$ act on the current $\boldsymbol{J_{2i}}$. It is the received energy of $\boldsymbol{J_{2i}}$. $\iiint_V (\boldsymbol{E_{1i}} \cdot \partial \boldsymbol{D_{2i}} + \boldsymbol{E_{2i}} \cdot \partial \boldsymbol{D_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}}) dV$ is the increased energy inside the volume V. In the time $t = 0$ to the end $t = T + \Delta t$, this energy is begin with 0 and in the end time is also 0. This part can show the energy move from emitter to the absorber and in a particle time the energy stay at the place in the space between the emitter and the absorber.

Consider our readers perhaps are not all electric engineer, we make clear here why we say the left of the Eq.(7) is the emitted energy. In electrics, if there is an electric element with voltage U and current I, and they have same direction, we obtained power IU. This power is loss energy of this electric element. If U has the different direction with current I or it has 180 degree phase difference. This power is an output power to the system, i.e. this element actually is a power supply. In the power supply situation, the supplied power is $|IU| = -IU$. Hence $-IU$ express a power supply to the system. Similarly, $\iiint_V (\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{1i}}) dV$ is the loss power of absorber $\boldsymbol{J_{2i}}$. $-\iiint_V (\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{2i}}) dV$ is the energy supply of $\boldsymbol{J_{1i}}$.

Assume V_1 is a volume contains only the emitter $\boldsymbol{J_{1i}}$. In this case since there is a part of advanced wave and retarded wave and the retarded wave close the line linked the emitter and absorber are synchronous, the other part of energy is different in phase and perhaps and hence has very small contribution to the energy transfer. Hence this part of energy current should not as 0, i.e.,

(8)

$$\oiint_{\Gamma_1} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma \neq 0$$

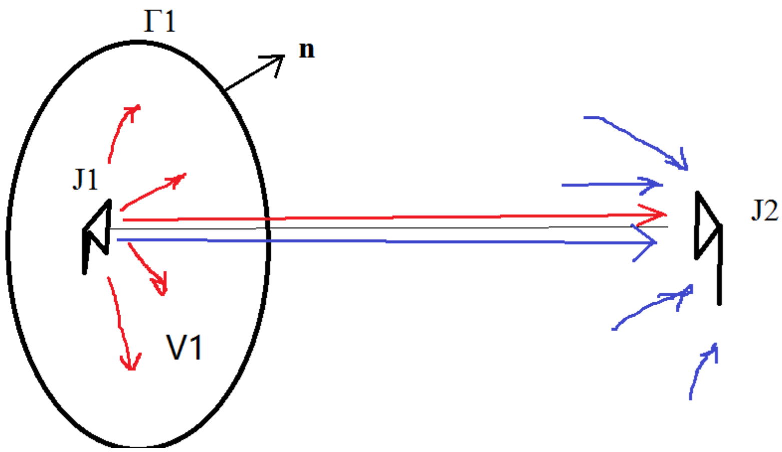


Figure 2., Red arrow is retarded wave, blue line is advanced wave. The arrow direction shows the direction of the energy current. The emitter contains inside the volume V_1. Γ_1 is the boundary surface of V_1. The energy current consist of the retarded wave and the advanced wave.

Eq.(5) can be rewritten as,

(9)

$$-\iiint_{V_1} (\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{2i}}) dV = \oiint_{\Gamma_1} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$$

$$+ \iiint_{V_1} (\boldsymbol{E_{1i}} \cdot \partial \boldsymbol{D_{2i}} + \boldsymbol{E_{2i}} \cdot \partial \boldsymbol{D_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}}) dV$$

In this formula, $-\iiint_{V_1} (\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{2i}}) dV$ is the emitted energy. $\oiint_{\Gamma_1} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$ is the energy current from the emitter to the absorber. $\iiint_{V_1} (\boldsymbol{E_{1i}} \cdot \partial \boldsymbol{D_{2i}} + \boldsymbol{E_{2i}} \cdot \partial \boldsymbol{D_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}}) dV$ is the increase of the energy inside volume V_1. Figure 2 shows the picture of this situation. The red arrow is retarded wave. The blue arrow is the advanced wave. For retarded wave, the arrow direction is same as the wave direction. For the advanced wave the arrow direction is in the opposite direction of the wave. In the Figure 2, we always draw the arrow in the energy current directions.

Assume V_2 is the volume which contains only the absorber $\boldsymbol{J_{2i}}$, Eq.(5) can be written as

(10)

$$-\oint\!\!\oint_{\Gamma_2}(\boldsymbol{E_{1i}}\times\boldsymbol{H_{2i}}+\boldsymbol{E_{2i}}\times\boldsymbol{H_{1i}})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V_2}(\boldsymbol{J_{2i}}\cdot\boldsymbol{E_{1i}})dV$$

$$+\iiint_{V_2}(\boldsymbol{E_{1i}}\cdot\partial\boldsymbol{D_{2i}}+\boldsymbol{E_{2i}}\cdot\partial\boldsymbol{D_{1i}}+\boldsymbol{H_{2i}}\partial\boldsymbol{B_{1i}}+\boldsymbol{H_{2i}}\partial\boldsymbol{B_{1i}})dV$$

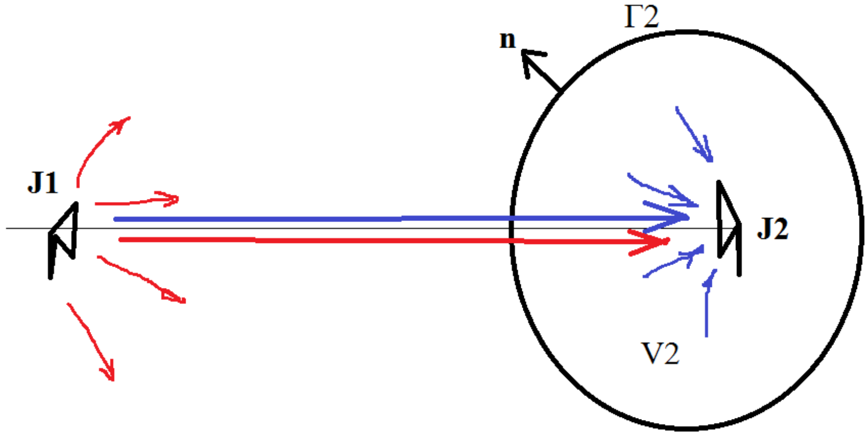


Figure 3. Choose the volume V_2 is close to the absorber. Red arrows are retarded wave, blue arrows are advanced wave. The direction of retarded wave is same as the direction of red arrow. The direction of advanced wave is at the opposite direction of the blue arrow. The arrow direction (red or blue) is always at the energy transfer direction.

From the above discussion it is clear that,

I. $\oint\!\!\oint_{\Gamma}(\boldsymbol{E_{1i}}\times\boldsymbol{H_{2i}}+\boldsymbol{E_{2i}}\times\boldsymbol{H_{1i}})\cdot\vec{\boldsymbol{n}}d\Gamma$ can be seen as energy current on the surface Γ (or energy flux).

II. $\partial u_{12}=(\boldsymbol{E_{1i}}\cdot\partial\boldsymbol{D_{2i}}+\boldsymbol{E_{2i}}\cdot\partial\boldsymbol{D_{1i}}+\boldsymbol{H_{2i}}\partial\boldsymbol{B_{1i}}+\boldsymbol{H_{2i}}\partial\boldsymbol{B_{1i}})$ is the increase of the photon energy distribution.

III. $\iiint_V \partial u_{12i}\, dV$ is the energy increase in the volume V.

IV. $\iiint_{V_2}(\boldsymbol{J_{2i}}\cdot\boldsymbol{E_{1i}})dV$ is the absorbed energy of the absorber.

V. $-\iiint_{V_1}(\boldsymbol{J_{1i}}\cdot\boldsymbol{E_{2i}})dV$ is the emitted energy which can be seen as the sucked energy by the advanced wave $\boldsymbol{E_{2i}}$ on the current $\boldsymbol{J_{1i}}$. Considering,

(11)

$$(\boldsymbol{E_{1i}}\cdot\partial\boldsymbol{D_{2i}}+\boldsymbol{E_{2i}}\cdot\partial\boldsymbol{D_{1i}}+\boldsymbol{H_2}\partial\boldsymbol{B_{1i}}+\boldsymbol{H_2}\partial\boldsymbol{B_{1i}})$$
$$=\boldsymbol{E_{1i}}\cdot\partial\epsilon\boldsymbol{E_{2i}}+\boldsymbol{E_{2i}}\cdot\partial\epsilon\boldsymbol{E_{1i}}+\boldsymbol{H_{2i}}\partial\mu\boldsymbol{H_{1i}}+\boldsymbol{H_{2i}}\partial\mu\boldsymbol{H_{1i}}$$
$$=\partial(\epsilon\boldsymbol{E_{1i}}\cdot\boldsymbol{E_{2i}}+\mu\boldsymbol{H_{1i}}\cdot\boldsymbol{H_{2i}})=\partial u_{12i}$$

Where $u_{12i} = \epsilon \boldsymbol{E_{1i}} \cdot \boldsymbol{E_{2i}} + \mu \boldsymbol{H_{1i}} \cdot \boldsymbol{H_{2i}}$. We have assume ϵ and μ are constant. We know $u_{12i} \neq 0$ take place at $t = 0$ to $t = T + \Delta t$. We can assume that $u_{12i}(t = -\infty) = u_{12}(t = +\infty) = constant$

(12)

$$\int_{-\infty}^{\infty} dt \iiint_{V_i} \partial u_{12i}\, dV$$

$$= \iiint_{V_i} u_{12i}(t = +\infty) - u_{12i}(t = -\infty) = 0$$

This means after the photon is go through from emitter to the absorber the energy in the space should recover to the original amount. Considering the above formula, from Eq.(7) we can obtain,

(13)

$$-\int_{-\infty}^{\infty} dt \iiint_{V} (\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{2i}}) dV = \int_{-\infty}^{\infty} dt \iiint_{V} (\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{1i}}) dV$$

This means all energy emitter from the current $\boldsymbol{J_{1i}}$ which is the left of the above formula is received by absorber $\boldsymbol{J_{2i}}$ which is the right of the above formula.

Considering Eq.(9,10 and 12,13) we have

(14)

$$\int_{-\infty}^{\infty} dt \oiint_{\Gamma_1} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$$

$$= \int_{-\infty}^{\infty} dt \oiint_{\Gamma_2} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot (-\vec{\boldsymbol{n}}) d\Gamma$$

The above formula tells us the all energy send out from Γ_1 flows into (please notice the minus sign in the right) the surface Γ_2. Consider the surface Γ_1 and Γ_2 is arbitrarily, that means in any surface between the emitter and the absorber has the same integral with same amount of the mutual energy current.

Define $Q_{mi} = \oiint_{\Gamma_m} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$, here we change the direction of $\vec{\boldsymbol{n}}$ always from the emitter to the absorber, then we can get the following, see Figure 4.

(15)

$$\int_{-\infty}^{\infty} dt\, Q_{mi} = \int_{-\infty}^{\infty} dt\, Q_{1i} \qquad i = 1,2,3,4,5$$

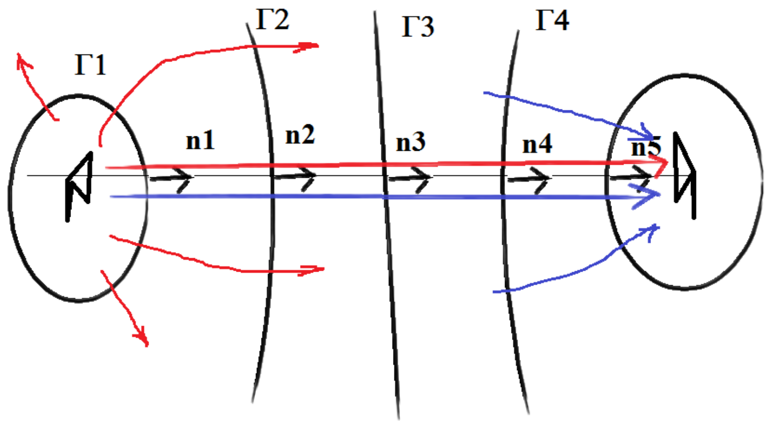


Figure 4. 5 surface is shown, the mutual energy current through each surface integral with time should be equal to each other.

From Figure 4 we can see that the time integral of the mutual energy current on an arbitrary surface are Γ_i are all the same, which are the energy transfer of the photon. In the place close to the emitter or absorber, the surface can be very small close to the size of the electron or atom. When energy is concentred to a small region the moment should also concentred to that small region. In this case the energy of this mutual energy current will behaved like a particle. However, it is still mutual energy current in 3D-space.

Figure 4 and Eq.(15) tell us the energy transfer with the mutual energy current can be approximately seen as a 1-D plane wave i.e. a wave in a wave guide. But the wave is actually as 3D wave, this allow the wave can go through the space other than empty space, for example double stilts. The mutual energy current has no any problem to go through the double slits and produce interference in the screen after the slits. This offers a clear interpretation for particle and wave duality of the photon.

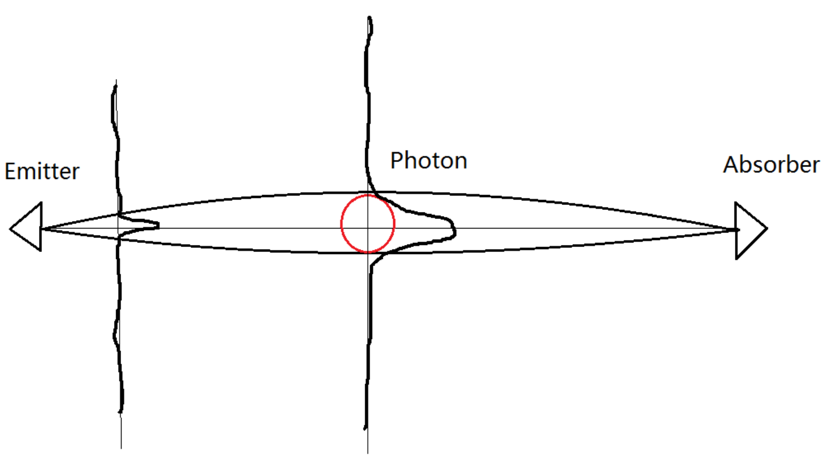


Figure 5. Photon in empty space, photon is just the mutual energy current. In some time, the photon is stayed at a place. This shows there is nothing about the concept of the wave function collapse.

5. Self-energy items

Which equations photon should satisfy? First we think Maxwell equations. But it is clear Maxwell equations can only obtain the continual solution. But Photon is a particle, its energy is sent to an absorber direction instead sent to the whole directions. This tell us we cannot simply ask photon to satisfy Maxwell equations. Does photon satisfy Schrodinger wave equation? Schrodinger wave equation is scale equation, when there are many photons, the superimposed fields should satisfy Maxwell equations which is vector equations. Hence photon cannot satisfy Schrodinger wave equation. We are interesting to know which equations photon should satisfy. when the number of photon become infinite, from these equations the Maxwell equations should be derived.

In the photon model of last section, if only considers the mutual energy current, there is no thing call wave function collapse. Everything is fine. However, in the Poynting theorem there are self-energy items, this section we need give a details of discussion about the self-energy items.

In this section we need to consider the self-energy items Eq.(3 and 4). The advanced wave and retarded wave all send to all directions instead send to only along the line linked the emitter and absorber. In this model the absorber doesn't absorb all retarded wave of the emitter. The emitter doesn't absorb all advanced wave from absorber. The self-energy current of the wave in Eq.(3 and 4) is sent to infinite. We can assume

(a) The self-energy items have no contribution to the energy transfer. This is because this kind of energy cannot be absorbed by any things if it doesn't collapse. It need to collapse to a point to be absorbed. When mutual energy current can transfer energy, there is no any requirement for the wave to collapse. We can think the emitter send also an advanced wave and emitter also send a retarded wave which made the emitter doesn't loss or increase energy through the self-energy. The absorber is also similar to the emitter, it sends the advanced self- current and also retarded wave. The absorber doesn't loss or increase energy through the self-energy current items.

(b) The self-energy items are existent, thy just send to infinite. Because for the whole system with an emitter and an absorber there are one advanced wave and a retarded wave both send to infinite the pure total energy did not loss for a system with emitter and absorber. The retarded wave loss some energy, but the advanced wave gains the same amount of energy. The part of energy can be seen as it is transferred from the emitter to the infinite and reflect back to become advanced wave of the absorber and received by the absorber. In this concept the self-energy transfers some energy from emitter to the absorber.

The idea of (a) has been applied to any current distribution ether an emitter or an absorber in which it sends a half retarded wave and a half retarded wave in Wheeler and Feynman. Hence no pure loss of energy for this kind of emitter or absorber. The idea of (b) should also be acceptable. The retarded wave send from emitter is reflect from infinite become advanced wave of the absorber. This concept has the same effect as the wave is collapses to the absorber but it is more easily to be acceptable. We can also say the self-energy parts of wave are collapsed through infinite far away. The only difficult for this kind of energy transfer is that if there is metal container, and if the emitter and the absorber are all inside the container, how the self-energy current send to infinite? We can think the retarded self-energy current send the surface of metal container become advanced wave of the absorber. But since the positions of emitter and absorber are in any places inside the container and the container can be any shape, there is no any electromagnetic theory can support this concept. Hence for this idea of (b) there is still some problem. However, in the following we will still continue working at the idea (b) and we will prove that the Poynting theorem is satisfied in macrocosm.

For idea (a) we can show even we throw away the self-energy items, it doesn't violate the Maxwell equations. After we throw away Eq.(3 and 4), there is only equation Eq.(5) left. We start from Eq.(5) to prove the Poynting theorem in macrocosm.

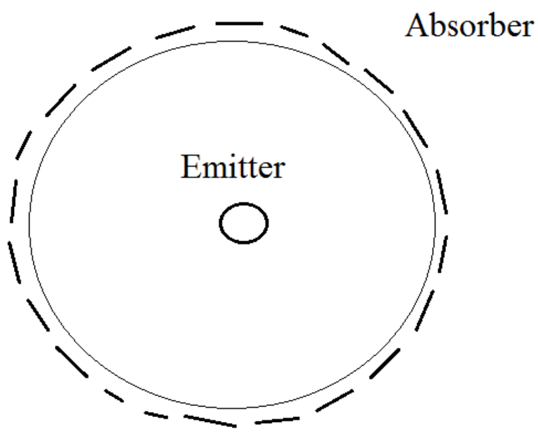


Figure 5. This shows emitters all at the center of the sphere. The absorbers are distributed at the surface of the sphere. The absorbers are the environment. We assume the absorbers are surrounded the emitters. This is our simplified macrocosm model.

Assume the emitters send retarded wave randomly with time. In the environment there are many absorbers in all directions which can absorb this waves. This is our simplified macrocosm model see Figure 5.

(1) **Assume self-energy doesn't vanish corresponding to the idea (b)**

We actually endorse the idea (a), but first we check the idea (b), see if we don't worry about the situation in which the emitter and the absorber are all inside a metal container.

We need to show that for (b) Maxwell equations are still satisfy for the macrocosm. Assume for the $\boldsymbol{i}$-th photon the items of self-energy doesn't vanish, i.e.,

(16)

$$-\oiint_{\Gamma} (\boldsymbol{E}_{\boldsymbol{1i}} \times \boldsymbol{H}_{\boldsymbol{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\mathbf{J}_{\mathbf{1i}} \cdot \boldsymbol{E}_{\boldsymbol{1i}} + \partial u_{\boldsymbol{1i}}) dV$$

(17)

$$-\oiint_{\Gamma} (\boldsymbol{E}_{\boldsymbol{2i}} \times \boldsymbol{H}_{\boldsymbol{2i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\mathbf{J}_{2i} \cdot \boldsymbol{E}_{\boldsymbol{2i}} + \partial u_{\boldsymbol{2i}}) dV$$

Assume for the i-th photon there is mutual energy current which satisfy:

(18)

$$-\oiint_{\Gamma} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\mathrm{\mathbf{J}_{1i}} \cdot \boldsymbol{E_{2i}} + \mathrm{\mathbf{J}_{2i}} \cdot \boldsymbol{E_{1i}}) dV$$

$$+ \iiint_V (\boldsymbol{E_{1i}} \cdot \partial \boldsymbol{D_{2i}} + \boldsymbol{E_{2i}} \cdot \partial \boldsymbol{D_{1i}} + \boldsymbol{H_{2i}} \partial \boldsymbol{B_{1i}} + \boldsymbol{H_2} \partial \boldsymbol{B_{1i}}) dV$$

These 3 formulas actually tell us the photon should satisfy Poynting theorem, from the above equations can derive the Poynting theorem for the photon,

(19)

$$-\oiint_{\Gamma} (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \times (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\boldsymbol{J_{1i}} + \boldsymbol{J_{2i}}) \cdot (\boldsymbol{E_{2i}} + \boldsymbol{E_{1i}}) dV$$

$$+ \iiint_V (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \cdot \partial(\boldsymbol{D_{1i}} + \boldsymbol{D_{2i}}) + (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}) \partial(\boldsymbol{B_{1i}} + \boldsymbol{B_{2i}}) dV$$

Or we can take sum to the above formula it becomes,

(20)

$$-\sum_i \oiint_{\Gamma} (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \times (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \sum_i \iiint_V (\boldsymbol{J_{1i}} + \boldsymbol{J_{2i}}) \cdot (\boldsymbol{E_{2i}} + \boldsymbol{E_{1i}}) dV$$

$$+ \sum_i \iiint_V (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \cdot \partial(\boldsymbol{D_{1i}} + \boldsymbol{D_{2i}}) + (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}) \partial(\boldsymbol{B_{1i}} + \boldsymbol{B_{2i}}) dV$$

In another side, assume $\boldsymbol{J_1} = \sum_i \boldsymbol{J_{1i}}$ and $\boldsymbol{J_2} = \sum_i \boldsymbol{J_{2i}}, \boldsymbol{E_1} = \sum_i \boldsymbol{E_{1i}}, \boldsymbol{E_2} = \sum_i \boldsymbol{E_{2i}}$, and so on. Hence there is,

(21)

$$(\boldsymbol{E_1} + \boldsymbol{E_2}) \times (\boldsymbol{H_1} + \boldsymbol{H_2})$$

$$= (\sum_{\boldsymbol{i}} \boldsymbol{E_{1i}} + \sum_j \boldsymbol{E_{2j}}) \times (\sum_{\boldsymbol{m}} \boldsymbol{H_{1m}} + \sum_{\boldsymbol{n}} \boldsymbol{H_{2n}})$$

$$= \sum_{\boldsymbol{i}} \boldsymbol{E_{1i}} \times \sum_{\boldsymbol{m}} \boldsymbol{H_{1m}} + \sum_{\boldsymbol{i}} \boldsymbol{E_{1i}} \times \sum_{\boldsymbol{n}} \boldsymbol{H_{2n}} + \sum_j \boldsymbol{E_{2j}} \times \sum_{\boldsymbol{m}} \boldsymbol{H_{1m}} + \sum_j \boldsymbol{E_{2j}} \times \sum_{\boldsymbol{n}} \boldsymbol{H_{2n}}$$

We have known photon is a particle that means all energy of photon sends out from an emitter has to be received by only one absorber. Hence only the items with $i = j$ doesn't vanish. Hence we have

(22)

$$\sum_i \boldsymbol{E_{1i}} \times \sum_m \boldsymbol{H_{1m}} = \sum_{im} \boldsymbol{E_{1i}} \times \boldsymbol{H_{1m}} = \sum_i \boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}$$

In the above, considering $\boldsymbol{E_{1i}} \times \boldsymbol{H_{1m}} = \boldsymbol{0}, \boldsymbol{if\ i \neq m.}$ This means that the field of i-th absorber only action to i-th emitter. Similar to other items, hence we have

(23) $$(\boldsymbol{E_1} + \boldsymbol{E_2}) \times (\boldsymbol{H_1} + \boldsymbol{H_2}) =$$

$$= \sum_i (\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} + \boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}})$$

$$= \sum_i (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \times (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}})$$

And similarly we have,

$$(\boldsymbol{J_1} + \boldsymbol{J_2}) \times (\boldsymbol{E_1} + \boldsymbol{E_2})$$

$$= \sum_i (\boldsymbol{J_{1i}} + \boldsymbol{J_{2i}}) \times (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}})$$

$$(\boldsymbol{E_1} + \boldsymbol{E_2}) \cdot \partial(\boldsymbol{D_1} + \boldsymbol{D_2}) = \sum_i (\boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}) \cdot \partial(\boldsymbol{D_{1i}} + \boldsymbol{D_{2i}})$$

$$(\boldsymbol{H_1} + \boldsymbol{H_2}) \cdot \partial(\boldsymbol{B_1} + \boldsymbol{B_2}) = \sum_i (\boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}) \cdot \partial(\boldsymbol{B_{1i}} + \boldsymbol{B_{2i}})$$

Considering Eq.(23), Eq.(20) can be written as,

(24)
$$-\oiint_\Gamma (\boldsymbol{E_1} + \boldsymbol{E_2}) \times (\boldsymbol{H_1} + \boldsymbol{H_2}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\boldsymbol{J_1} + \boldsymbol{J_2}) \cdot (\boldsymbol{E_2} + \boldsymbol{E_1}) dV$$

$$+ \iiint_V (\boldsymbol{E_1} + \boldsymbol{E_2}) \cdot \partial(\boldsymbol{D_1} + \boldsymbol{D_2}) + (\boldsymbol{H_1} + \boldsymbol{H_2}) \partial(\boldsymbol{B_1} + \boldsymbol{B_2}) dV$$

If we take $V = V_1$ which only contains the current of $\boldsymbol{J_1}$ that means the current of environment $\boldsymbol{J_2}$ is put out side of the volume V_1, we have,

(25)
$$-\oiint_{\Gamma_1} (\boldsymbol{E_1} + \boldsymbol{E_2}) \times (\boldsymbol{H_1} + \boldsymbol{H_2}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_{V_1} \boldsymbol{J_1} \cdot (\boldsymbol{E_2} + \boldsymbol{E_1}) dV$$

$$+ \iiint_{V_1} (\boldsymbol{E_1} + \boldsymbol{E_2}) \cdot \partial(\boldsymbol{D_1} + \boldsymbol{D_2}) + (\boldsymbol{H_1} + \boldsymbol{H_2}) \partial(\boldsymbol{B_1} + \boldsymbol{B_2}) dV$$

Considering the total fields can be seen as the sum of the retarded wave and advanced wave. In the macrocosm we don not know whether the field is produced by the retarded field of the emitter current $\boldsymbol{J_1}$ or produced by the advanced wave of the absorber in the environment. We can think all the field is produced by the source current $\boldsymbol{J_1}$, hence we have $\boldsymbol{E}=\boldsymbol{E_1}+\boldsymbol{E_2}$, $\boldsymbol{D}=\boldsymbol{D_1}+\boldsymbol{D_2}$, $\boldsymbol{H}=\boldsymbol{H_1}+\boldsymbol{H_2}$, $\boldsymbol{B}=\boldsymbol{B_1}+\boldsymbol{B_2}$. Here the field $\boldsymbol{E},\boldsymbol{H}$ are total electromagnetic field which are thought produced by emitter $\boldsymbol{J_1}$, hence we have

(26)

$$-\oiint_{\Gamma_1}\boldsymbol{E}\times\boldsymbol{H}\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V_1}\boldsymbol{J_1}\cdot\boldsymbol{E}dV$$

$$+\iiint_{V_1}(\boldsymbol{E}\cdot\partial\boldsymbol{D}+\boldsymbol{H}\partial\boldsymbol{B})dV$$

This is the Poynting theorem in macrocosm. In this formula there is only emitter current $\boldsymbol{J_1}$. The field $\boldsymbol{E},\boldsymbol{H}$ can be seen as retarded wave but it is actually consist of both retarded wave and advanced wave.

We have started with assume microcosm photon model where the field is produced from the advanced wave of the absorber and the retarded wave of the emitter. We assume that the self-energy items doesn't vanish, we obtained the macrocosm Poynting theorem, in which the field is assumed that the field is produced only by the emitters. We know that Poynting theorem is nearly equivalent to Maxwell equations. Although from Poynting theorem we cannot deduce Maxwell equations, but Poynting theorem can derive all reciprocity theorem, from reciprocity theorem we can obtained the green function solution of Maxwell equations. From all solution of Maxwell equations, the Maxwell equations should be possible to be induced from their all solutions.

The above proof is not trivial. We have shown that if photon consist of self-energy and mutual energy items of an advanced wave and a retarded wave, the electromagnetic field which is sum of all fields of the emitters and absorbers still satisfy Poynting theorem and hence also Maxwell equations.

In our macrocosm model, the emitters are at one point and all the absorbers are at a sphere. However, this can be easily widened to more generalized situation in which the emitters are not only stay at one point and the absorbers are not only on a sphere surface but in the whole.

(2) Assume self energy don't transfer energy

When the emitter and the absorber stayed inside a metal container, the self-energy becomes difficult to transfer. Hence in this section we continue to study when the self-energy currents don't contribute to the energy transfer.

In this situation all self-energy items don't transfer energy. The energy of photon is transferred only through the mutual energy items. Emitter sends retarded self-energy. We can assume the emitter also send an advanced wave which have the same energy current as the retarded self-energy but has opposite direction of energy transfer. Hence the total energy transfer of self-energy for the emitter vanishes. It is similar to the absorber. The absorber has advanced self-energy current items. We assume the absorber also sends a retarded wave out which has same amount of energy current as the self-energy current of the absorber and has opposite direction. Hence the total energy of transfer of self-energy of the absorber also vanishes. We will study the situation there is only the mutual energy items which contributed to the energy current. By the way, the retarded wave of the absorber begins at time $\mathrm{t} = \mathrm{T}$. When this wave reached to the emitter, it is time $\mathrm{t} = 2\mathrm{T}$. If the emitter sends the advanced wave also at $\mathrm{t} = 2\mathrm{T}$, these two wave can be synchronized. However, in the above when we speak about the emitter send retarded wave and also advanced wave, both waves are started at time $\mathrm{t} = 0$. The emitter sends the advanced wave at the same time as it sends the retarded wave. Hence, the retarded wave of the absorber and the advanced wave of the emitter cannot be synchronized and hence cannot produce any mutual energy current. There existent only the mutual energy current between the retarded wave of emitter and advanced wave of the absorber.

Assume one of the current of emitters is $\boldsymbol{J}_{1i}$, which is at the origin and the current of the corresponding absorber is $\boldsymbol{J}_{2i}$, which is at the sphere, see Figure 5, here $\mathrm{i} = 0,1, \dots N$. We can apply mutual energy theorem to this pair of emitter and absorber, we obtain, Eq.(5) can be written as,

$$\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{r}} = \boldsymbol{J}_{1\mathrm{i}}^{\mathrm{a}} = \boldsymbol{J}_{1i}$$

$$\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{r}} = \boldsymbol{J}_{2\mathrm{i}}^{\mathrm{a}} = \boldsymbol{J}_{2i}$$

$\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{r}}$ can only produce retarded wave. $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{a}}$ and $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{a}}$ can only produce advanced wave. $\boldsymbol{J}_{1i}$ can be replaced with $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{a}}$. $\boldsymbol{J}_{2i}$ can be replaced with $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{a}}$. We assume that the mutual energy current happens only between $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{a}}$, which is,

(27)

$$-\oint\!\!\!\oint_{\Gamma} \sum_i (\boldsymbol{E}_{1i}^{r} \times \boldsymbol{H}_{2i}^{a} + \boldsymbol{E}_{2i}^{a} \times \boldsymbol{H}_{1i}^{r}) \cdot \vec{\boldsymbol{n}} d\Gamma$$

$$= \iiint_V \sum_i (\boldsymbol{J}_{1i}^{r} \cdot \boldsymbol{E}_{2i}) dV + \iiint_V \sum_i (\boldsymbol{J}_{2i}^{a} \cdot \boldsymbol{E}_{1i}) dV$$

$$+ \iiint_V \sum_i (\boldsymbol{E}_{1i}^{r} \cdot \partial \boldsymbol{D}_{2i}^{a} + \boldsymbol{E}_{2i}^{a} \cdot \partial \boldsymbol{D}_{1i}^{r} + \boldsymbol{H}_{2i}^{a} \partial \boldsymbol{B}_{1i}^{r} + \boldsymbol{H}_{2i}^{a} \partial \boldsymbol{B}_{1i}^{r})\, dV$$

$\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{a}}$ do not produce any mutual energy current because this two fields are not synchronized.

If $\boldsymbol{J}_{2\mathrm{i}}^{\mathrm{r}}$ and $\boldsymbol{J}_{1\mathrm{i}}^{\mathrm{a}}$ also produce some mutual energy current, then we can prove there are an energy current transferred from absorber to the emitter, which makes the whole system of an emitter and an absorber doesn't transfer any energy. This situation is trivial and is not what would like to discuss.

We assume the field of emitter $\boldsymbol{J}_{1i}^{r}$ can only be received by the absorber $\boldsymbol{J}_{2i}^{a}$, here $i = 1, \dots, \mathrm{N}$. This requirement is asked because that the photon is a particle and all its energy must be received by only one absorber. The whole package of energy should be received by only one absorber. That means for example, assume that $\boldsymbol{J}_1^{r} = \sum_i \boldsymbol{J}_{1\mathrm{i}}^{r}$ and $\boldsymbol{J}_2^{a} = \sum_j \boldsymbol{J}_{2j}^{a}$, $\boldsymbol{E}_1^{r} = \sum_i \boldsymbol{E}_{1i}^{r}$, $\boldsymbol{E}_2^{a} = \sum_i \boldsymbol{E}_{2i}^{a}$, consider this, Eq.(27) becomes

(28)

$$-\oint\!\!\!\oint_{\Gamma} (\boldsymbol{E}_1^{r} \times \boldsymbol{H}_2^{a} + \boldsymbol{E}_2^{a} \times \boldsymbol{H}_1^{r}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\boldsymbol{J}_1^{r} \cdot \boldsymbol{E}_2^{a}) dV + \iiint_V (\boldsymbol{J}_2^{a} \cdot \boldsymbol{E}_1^{r}) dV$$

$$+\iiint_V (\boldsymbol{E}_1^r \cdot \partial \boldsymbol{D}_2^a + \boldsymbol{E}_2^a \cdot \partial \boldsymbol{D}_1^r + \boldsymbol{H}_2^a \partial \boldsymbol{B}_1^r + \boldsymbol{H}_2^a \partial \boldsymbol{B}_1^r) dV$$

In the above formula we have considered that

$$\sum_{ij} \boldsymbol{E}_{1i}^r \times \boldsymbol{H}_{2j}^a = \boldsymbol{0}$$

This means that only the field of the i-th emitter and the i-th absorber can have no zero energy transfer. The energy will as a whole package only send from i-th emitter to the i-th absorber. And hence, there is,

$$\sum_i \boldsymbol{E}_{1i}^r \times \sum_J \boldsymbol{H}_{2j}^a = \sum_{ij} \boldsymbol{E}_{1i}^r \times \boldsymbol{H}_{2j}^a = \sum_i \boldsymbol{E}_{1i}^r \times \boldsymbol{H}_{2i}^a$$

Similarly to other items. We assume all the advanced waves average should close to the retarded wave that is,

(29)

$$\sum_i \boldsymbol{E}_{1i}^r = \sum_i \boldsymbol{E}_{2i}^a \equiv \frac{\boldsymbol{1}}{\boldsymbol{2}} \boldsymbol{E}$$

$$\sum_i \boldsymbol{H}_{1i}^r = \sum_i \boldsymbol{H}_{2i}^a \equiv \frac{\boldsymbol{1}}{\boldsymbol{2}} \boldsymbol{H}$$

(30)

The above formula tell us that the total retarded wave field $\sum_i \boldsymbol{H}_{1i}$ is half of the macrocosm field. The total advanced waves from all photons $\sum_i \boldsymbol{E}_{2i}$ is the half of the macrocosm field.

Where "≡" means "is defined as". Considering the above formula, we obtain,

(31)

$$\frac{\boldsymbol{1}}{\boldsymbol{2}} \oiint_\Gamma (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma = \frac{\boldsymbol{1}}{\boldsymbol{2}} \iiint_V (\boldsymbol{J}_1^r \cdot \boldsymbol{E}) dV + \frac{\boldsymbol{1}}{\boldsymbol{2}} \iiint_V (\boldsymbol{J}_2^a \cdot \boldsymbol{E}) dV$$

$$+\frac{\boldsymbol{1}}{\boldsymbol{2}} \iiint_V (\boldsymbol{E} \cdot \partial \boldsymbol{D} + \boldsymbol{H} \cdot \partial \boldsymbol{B}) dV$$

We can choose V as V_1 which is very small volume close to emitter, in that case, $\boldsymbol{J}_2$ is at outside of V_1 and the middle item in the right of the above formula vanishes, and hence we obtain,

(32)

$$-\iiint_{V_1} (\boldsymbol{J}_1 \cdot \boldsymbol{E}) dV = [\oiint_{\Gamma_1} (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma + \iiint_{V_1} (\boldsymbol{E} \cdot \partial \boldsymbol{D} + \boldsymbol{H} \cdot \partial \boldsymbol{B}) dV]$$

Comparing to Eq.(26), the above equation is the Poynting theorem in Macrocosm. It is noticed that, the self-energy items of the emitter,

(33)

$$-\oiint_{\Gamma}(\boldsymbol{E}_{1i}^{r}\times\boldsymbol{H}_{1i}^{r})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V}(\mathbf{J}_{1\mathbf{i}}^{\mathbf{r}}\cdot\boldsymbol{E}_{1i}^{r}+\partial u_{1i}^{r})dV$$

Is cancelled with the advanced items,

(34)

$$-\oiint_{\Gamma}(\boldsymbol{E}_{1i}^{a}\times\boldsymbol{H}_{1i}^{a})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V}(\mathbf{J}_{1\mathbf{i}}^{\mathbf{a}}\cdot\boldsymbol{E}_{1i}^{a}+\partial u_{1i}^{a})dV$$

The advanced items of the absorber

(35)

$$-\oiint_{\Gamma}(\boldsymbol{E}_{2i}^{a}\times\boldsymbol{H}_{2i}^{a})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V}(\mathbf{J}_{2i}^{\mathbf{a}}\cdot\boldsymbol{E}_{2i}^{a}+\partial u_{2i}^{a})dV$$

Is cancelled with a retarded item,

(36)

$$-\oiint_{\Gamma}(\boldsymbol{E}^{r}{}_{2i}\times\boldsymbol{H}_{2i}^{r})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_{V}(\mathbf{J}_{2i}^{\mathbf{r}}\cdot\boldsymbol{E}_{2i}^{r}+\partial u_{2i}^{a})dV$$

(3) Summary

In this section we have introduced two methods to deal with the self-energy items of the energy transfer. One is that this kind transfer of self-energy existent. The self-energy current of the retarded wave of the emitter sends to infinity and reflected at the end of the cosmos, becomes the advanced wave of the absorber, hence this energy is send from the emitter to the absorber. The self-energy items transferred half total energy, the other half part of energy is transferred by the mutual energy current. The only problem of this assumption is that if the emitter and the absorber are not at infinite empty space but inside a metal container, we still have to assume the self-energy items can be sent to infinity, this seems isn't possible. Hence we made another assumption. Another is that the transfer of self-energy doesn't have any contribution to the energy transfer. Self-energy items are cancelled. This assumption is similar to the model J. A. Wheeler and R. P. Feynman. The current will produce half-retarded wave and half advanced wave for bother emitter and absorber. We assume that the mutual energy current is only produced between retarded wave of the emitter and the advanced wave of the absorber. If the mutual energy current is produced between the retarded wave of the absorber and the advanced wave of the emitter, then the absorber is actually an emitter and the emitter is actually an absorber. In this situation we can just exchange the emitter and the absorber.

J. Crammer introduced the concept of continually collapse that means 3D wave continually collapse to a 1-D wave [3-5]. In the authors' photon model, the energy transfer is also very close to a 1-D wave. The transferred energy current in any surface is same. There is no wave function collapse or continually collapse.

In the authors' photon model, the self-energy current of the photon has no contribution to the energy current. We have proven that the macrocosm Poynting theorem can be derived from our photon model. Even the self-energy of microcosm vanishes, the self-energy items in macrocosm which is Poynting theorem do not vanish. In macrocosm Poynting theorem the self-energy items actually is produced by a summation of mutual energy current items. Hence we can say the macrocosm self energy is produced by the microcosm mutual energy current.

For the mutual energy current, the energy transfer is centered at the line linked the emitter and the absorber. However, we derived it from a 3D radiation picture. The mutual energy current can go any other light road, for example the double slits.

The wave function collapse in quantum physics actually comes from the misunderstandings that the wave energy is transferred by Poynting energy current or self-energy current. In this case the retarded energy transferred from emitter must collapse to the absorber. The advanced wave transfer negative energy from absorber to the emitter has to collapse to the emitter. However, we have proven that the mutual energy current can transfer the energy too, in this case we can easily throw away the self-energy current items, let the mutual energy current to take over the task originally should be done by self-energy current. The concept of the wave function collapse of quantum physics isn't need any more in our photon model.

This section tells us, if photon is composed as an emitter and an absorber, and the emitter sends retarded wave and the absorber send advanced wave, and photon satisfy mutual energy theorem in microcosm, then the system with infinite photons should satisfy Poynting theorem in macrocosm, which make it in turn satisfy Maxwell equations (Poynting theorem is equivalent to Maxwell equations in practical). This means also that the mutual energy current, the mutual energy theorem are more fundamental concepts than the self-energy current and Poynting theorem in microcosm.

6. The photon equations

Photon's equation doesn't need to satisfy exactly Maxwell equations. However, all photon put together it be come macrocosm field which must satisfy Maxwell equations. Originally we thought the photon equation perhaps have a little difference with Maxwell equations. But from the above derivation the equations of the photon satisfy exactly the Maxwell equations. The following equation produced the advanced wave from the emitter

(37)

$$\nabla \times \boldsymbol{E}_{1i}^{a} = -\mu \partial \boldsymbol{H}_{1i}^{a}$$
$$\nabla \times \boldsymbol{H}_{1i}^{a} = \boldsymbol{J}_{1i}^{a} + \epsilon \partial \boldsymbol{E}_{1i}^{a}$$

(38)

$$\nabla \times \boldsymbol{E}_{1i}^{r} = -\mu \partial \boldsymbol{H}_{1i}^{r}$$
$$\nabla \times \boldsymbol{H}_{1i}^{r} = \boldsymbol{J}_{1i}^{r} + \epsilon \partial \boldsymbol{E}_{1i}^{r}$$

(39)

$$\boldsymbol{J}_{1i}^{a} = \boldsymbol{J}_{1i}^{r} = \boldsymbol{\delta}(\boldsymbol{t})\boldsymbol{\delta}(\boldsymbol{x})\boldsymbol{\delta}(\boldsymbol{y})\boldsymbol{\delta}(\boldsymbol{z})\vec{\boldsymbol{z}}$$

The equations for the absorber are,

(40)

$$\nabla \times \boldsymbol{E}_{2i}^{a} = -\mu \partial \boldsymbol{H}_{2i}^{a}$$

$$\nabla \boldsymbol{H}_{2i}^{a} = \boldsymbol{J}_{2i}^{a} + \epsilon \partial \boldsymbol{E}_{2i}^{a}$$

(41)

$$\nabla \times \boldsymbol{E}_{2i}^{r} = -\mu \partial \boldsymbol{H}_{2i}^{r}$$

$$\nabla \boldsymbol{H}_{2i}^{r} = \boldsymbol{J}_{2i}^{r} + \epsilon \partial \boldsymbol{E}_{2i}^{r}$$

(42)

$$\boldsymbol{J}_{2i}^{a} = \boldsymbol{J}_{2i}^{r} = \boldsymbol{\delta}(\boldsymbol{t} - \boldsymbol{T})\boldsymbol{\delta}(\boldsymbol{x} - \boldsymbol{X})\boldsymbol{\delta}(\boldsymbol{y})\boldsymbol{\delta}(\boldsymbol{z})\vec{\boldsymbol{x}}$$

We assume that the current of the emitter is at the origin and time $t = 0$. The absorber is at X-axis of the place X. The authors are very glad that we obtained that the Photon also satisfy the Maxwell equations.

Since that the current of absorber normally do not cause any energy transfer. The self-energy current of the advanced wave and the retarded wave cancels each other. We can assume that the current of the emitter and the current of absorber are often not zero. Normally this current only produce the self energy, which is half retarded wave and half advanced wave and hence cancelled each other without any contribution to energy transfer. However, if in the time the emitter send a retarded wave just reached the absorber, if in this time, the absorber also sends an advanced wave then, the mutual energy current will produce and in this situation there is the energy transfer from emitter to the absorber. Since both emitter and the absorber only have very short time windows, only when this time windows exactly synchronized, the mutual energy current can happens. In the next section we will show that the current of the absorber and the current of the emitter must perpendicular to each other. This also reduce the possibility the emitter and the absorber can produce mutual energy current.

We assume

(43)

$$\boldsymbol{E}_{1i} = \boldsymbol{E}_{1i}^{r} + \boldsymbol{E}_{1i}^{a}$$

$$\boldsymbol{H}_{1i} = \boldsymbol{H}_{1i}^{r} + \boldsymbol{H}_{1i}^{a}$$

$$\boldsymbol{E}_{2i} = \boldsymbol{E}_{2i}^{r} + \boldsymbol{E}_{2i}^{a}$$

$$\boldsymbol{H}_{2i} = \boldsymbol{H}_{2i}^{r} + \boldsymbol{H}_{2i}^{a}$$

$$\boldsymbol{J}_{1} = \boldsymbol{J}_{1i}^{a} + \boldsymbol{J}_{1i}^{r}$$

$$\boldsymbol{J}_{2} = \boldsymbol{J}_{2i}^{a} + \boldsymbol{J}_{2i}^{r}$$

Here, $[\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$ is the total field of the emitter. $[\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$ is the total field of the absorber. We have known that the total field the self energy has no contribution. But $[\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$ can not vanish. That means

(44)

$$\nabla \cdot \boldsymbol{E}_{1i} \times \boldsymbol{H}_{1i} = \boldsymbol{0}$$

$$\nabla \cdot \boldsymbol{E}_{2i} \times \boldsymbol{H}_{2i} = \boldsymbol{0}$$

From this we can just further assume that

(45)

$$\boldsymbol{E}_{1i} \times \boldsymbol{H}_{1i} = \boldsymbol{0}$$

$$\boldsymbol{E}_{2i} \times \boldsymbol{H}_{2i} = \boldsymbol{0}$$

Hence, this means that $\boldsymbol{E}_{1i}||\boldsymbol{H}_{1i}$ and $\boldsymbol{E}_{2i}||\boldsymbol{H}_{2i}$, Here || means parallel with each other. Eq.(38) can be written as

$$\begin{aligned}\nabla \times (\boldsymbol{E}_{1i}^{a} + \boldsymbol{E}_{1i}^{r}) = -\mu\partial(\boldsymbol{H}_{1i}^{a} + \boldsymbol{H}_{1i}^{r}) \\ \nabla \times (\boldsymbol{H}_{1i}^{a} + \boldsymbol{H}_{1i}^{r}) = (\boldsymbol{J}_{1i}^{a} + \boldsymbol{J}_{1i}^{r}) + \epsilon\partial(\boldsymbol{E}_{1i}^{a} + \boldsymbol{E}_{1i}^{r})\end{aligned}$$

Or considering Eq.(43) we have,

(46)

$$\begin{aligned}\nabla \times \boldsymbol{E}_{1i} = -\mu\partial\boldsymbol{H}_{1i} \\ \nabla\boldsymbol{H}_{1i} = \boldsymbol{J}_{1} + \epsilon\partial\boldsymbol{E}_{1i}\end{aligned}$$

Similar we have

(47)

$$\begin{aligned}\nabla \times \boldsymbol{E}_{2i} = -\mu\partial\boldsymbol{H}_{2i} \\ \nabla\boldsymbol{H}_{2i} = \boldsymbol{J}_{2} + \epsilon\partial\boldsymbol{E}_{2i}\end{aligned}$$

To the field $[\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$**,** their self-energy items are cancelled and hence it is actually as retarded wave. To the field $[\boldsymbol{E}_{2i}, \boldsymbol{H}_{2i}]$, their self-energy items are cancelled and hence it is actually as advanced wave.

Assume

(48)

$$\begin{aligned}\boldsymbol{E}_{i} = \boldsymbol{E}_{1i} + \boldsymbol{E}_{2i} \\ \boldsymbol{H}_{i} = \boldsymbol{H}_{1i} + \boldsymbol{H}_{2i}\end{aligned}$$

Eq.(27) should be

(49)

$$-\oiint_{\Gamma} \sum_{i}(\boldsymbol{E}_{1i} \times \boldsymbol{H}_{2i} + \boldsymbol{E}_{2i} \times \boldsymbol{H}_{1i}) \cdot \vec{\boldsymbol{n}}d\Gamma$$

$$= \iiint_{V} \sum_{i}\boldsymbol{J}_{1i} \cdot \boldsymbol{E}_{2i})dV + \iiint_{V} \sum_{i}\boldsymbol{J}_{2i} \cdot \boldsymbol{E}_{1i})dV$$

$$+ \iiint_{V} \sum_{i}(\boldsymbol{E}_{1i} \cdot \partial\boldsymbol{D}_{2i} + \boldsymbol{E}_{2i} \cdot \partial\boldsymbol{D}_{1i} + \boldsymbol{H}_{1i}\partial\boldsymbol{B}_{2i} + \boldsymbol{H}_{2i}\partial\boldsymbol{B}_{1i})\, dV$$

Or

(50)

$$-\oiint_{\Gamma} (\boldsymbol{E_1} \times \boldsymbol{H_2} + \boldsymbol{E_2} \times \boldsymbol{H_1}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V \boldsymbol{J_1} \cdot \boldsymbol{E_2}\, dV + \iiint_V \boldsymbol{J_2} \cdot \boldsymbol{E_1}\, dV$$

$$+ \iiint_V (\boldsymbol{E_1} \cdot \partial \boldsymbol{D_2} + \boldsymbol{E_2} \cdot \partial \boldsymbol{D_1} + \boldsymbol{H_1} \partial \boldsymbol{B_2} + \boldsymbol{H_2} \partial \boldsymbol{B_1}) dV$$

$$\boldsymbol{E_1} = \boldsymbol{E_2} = \frac{\boldsymbol{1}}{\boldsymbol{2}} \boldsymbol{E}$$

$$\boldsymbol{H_1} = \boldsymbol{E_2} = \frac{\boldsymbol{1}}{\boldsymbol{2}} \boldsymbol{E}$$

(1)

$$-\frac{1}{2} \oiint_{\Gamma} (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma = \frac{1}{2} \iiint_V \boldsymbol{J_1} \cdot \boldsymbol{E}\, dV + \frac{1}{2} \iiint_V \boldsymbol{J_2} \cdot \boldsymbol{E}\, dV$$

$$+ \frac{1}{2} \iiint_V (\boldsymbol{E} \cdot \epsilon \partial \boldsymbol{E} + \boldsymbol{H} \cdot \mu \partial \boldsymbol{H})\, dV$$

or

$$- \oiint_{\Gamma} (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V \boldsymbol{J_1} \cdot \boldsymbol{E_2}\, dV + \iiint_V \boldsymbol{J_2} \cdot \boldsymbol{E_1}\, dV$$

$$+ \iiint_V (\boldsymbol{E} \cdot \epsilon \partial \boldsymbol{E} + \boldsymbol{H} \cdot \mu \partial \boldsymbol{H})\, dV$$

Take $V = V_1$ which is a volume only contains $\boldsymbol{J_1}$ we have obtains,

$$- \oiint_{\Gamma_1} (\boldsymbol{E} \times \boldsymbol{H}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_{V_1} \boldsymbol{J_1} \cdot \boldsymbol{E}\, dV$$

$$+ \iiint_{V_1} (\boldsymbol{E} \cdot \epsilon \partial \boldsymbol{E} + \boldsymbol{H} \cdot \mu \partial \boldsymbol{H})\, dV$$

This is the Poynting theorem in macrocosm. The photon model can be seen in Figure 6.

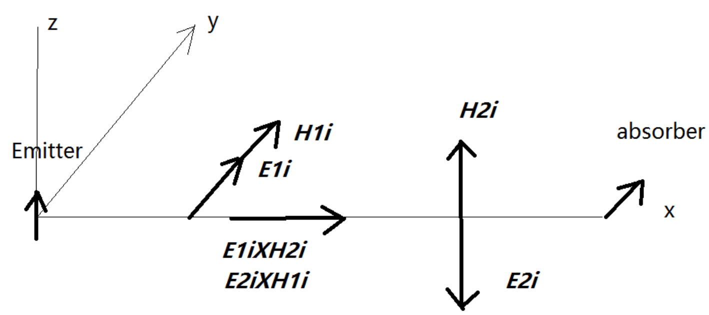


Figure 6. The photon model. The current of the absorber must be perpendicular to the current of the emitter. The electric field and the magnetic field of the emitter must have the same direction. The electric field of the absorber has the in the direction of perpendicular to the current of the emitter.

7. Polarization or spin of the photon

In the mutual energy current there is,

(2)

$$Q_{12i} = \oiint_{\Gamma} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$$

We assume that the current of the emitter is at the direction of $\vec{\boldsymbol{z}}$ and the absorber is at the direction of $\vec{\boldsymbol{x}}$, see figure 6. This can guarantee the two magnetic fields $\boldsymbol{H_{1i}}$ and $\boldsymbol{H_{2i}}$ are perpendicular**.** If the above two magnetic field are perpendicular, the electric field $\boldsymbol{E_{1i}}$ and $\boldsymbol{E_{2i}}$ will also be perpendicular or at least close to perpendicular.

there are two items in the above formula, $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ and $\boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}$, From Figure 6 we know along the line of from emitter to the absorber, $\boldsymbol{E_{1i}}$ just perpendicular to $\boldsymbol{E_{2i}}$**,** this made them perfectly to build a polarized field. If $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ has the same phase with the item $\boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}$, we obtain a linear polarized field. If the two items have 90 degree in phase difference, we will obtain a circular polarized field.

Originally in the time the authors write other article [15,16], they have thought that the circle polarization or spin of photon is caused by the two waves retarded wave and the advanced waves that have a phase difference and hence produces the polarization. If it is circle polarization, then it can be seen as spin. $\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}$ and $\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}}$ to produce the polarization. However, to produce polarization there need the two electric fields $\boldsymbol{E_{1i}}$ and $\boldsymbol{E_{2i}}$ must be perpendicular. They can not find a correct reason that the two electric fields $\boldsymbol{E_{1i}}$ and $\boldsymbol{E_{2i}}$ are perpendicular in that time. Now the above model tells us the two electric fields $\boldsymbol{E_{1i}}$ and $\boldsymbol{E_{2i}}$ are perpendicular if the current of absorber is perpendicular to the current of the emitter. It is interesting to notice this two items $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ and $\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}$ are both with the retarded field and the advanced wave. If the electric field is retarded wave of the emitter, then the corresponding magnetic field is advanced wave of the absorber and vice versa. Hence to the polarization or spin of the photon the emitter and the absorber must all involved. For the polarization or spin, the absorber is involved which is the actually the reason of the delayed choice experiment of the J. A. Wheeler [6].

We do not make assumption that the current of the absorber is caused by the retarded wave. Instead we assume the absorber sends advanced wave automatically. If the current of the absorber is caused by the retarded wave of the emitter, we have to answer the question that why this absorber react to the retarded wave instead of another absorber.

8. Summary

1. Photon current theorem: The emitter and absorber all sends retarded wave and advanced wave.
2. Self-energy current theorem: The retarded wave of the emitter is cancelled by the advanced wave of the emitter. The advanced wave of the absorber is cancelled by the retarded wave of the absorber. Hence, the self-energy current of emitter and absorber doesn't transfer any energy. This made the electric field of the emitter is parallel to the magnetic field of the emitter and made the electric field of the absorber is parallel to the magnetic field of the absorber. In microcosm, self-energy current doesn't transfer any energy. It seems the energy of emitter is transferred to the whole space by the retarded wave and later returned to it by the advanced wave. For absorber it sends negative energy to the space by the advanced wave and this negative energy is returned to it by the retarded wave of the absorber.
3. Mutual energy theorem: The retarded wave of the emitter and the advanced wave of the absorber together produce the mutual energy current. For the photon, the energy transfer from emitter to the absorber is done only by the mutual energy current.
4. Polarization and spin theorem. The current of absorber must perpendicular to the current of the emitter, only in this way the two magnetic fields produced by the emitter and produced by the absorber can be perpendicular to each other. This made the corresponding two electric fields also perpendicular. The two items in the mutual energy current produce the two items of the polarization. If the two items have no phase difference, it produces the linear polarization. If there is 90 degree difference in phase, the circle polarization is produced. The circle polarization is corresponding to the spin of the photon. For the polarization, the absorber paly an important role similar to the emitter.
5. Synchronization theorem: The mutual energy current must synchronized. That means only when the wave of the emitter reaches the absorber, in this time the absorber just sends its advanced wave, the two wave produce the mutual energy current. The two waves must have same frequency. The current of the absorber must perpendicular to the current of the emitter. We can assume the emitter and absorber always send the self-energy out, if there is no any mutual energy produced by the above mentioned synchronization, the self-energy (positive or negative) will return to the emitter or absorber, and hence can not have any influence to others. Only when the time windows, frequency of wave, the directions of current of the absorber and emitter, all this condition is satisfied, the mutual energy current can happens. The photon is just this mutual energy current. There is the possibility that two absorber satisfy the above condition in the same time. However, we assume this possibility is very low.
6. In macrocosm, Poynting theorem described the relation between the self-energy current and the current of the emitter. This macrocosm self-energy current is actually caused by infinite mutual current in microcosm. The microcosm self-energy current is all cancelled and hence has no any contribution to the macrocosm self-energy current.
7. If this photon model is correct, the mutual energy theorem in Fourier domain is a real physics theorem. The Lorentz reciprocity theorem is only a mathematic deformation of the mutual

energy theorem. Mutual energy theorem is actually more fundamental to the Poynting theorem and the reciprocity theorem.

9. Conclusion

The photon model is built. Photon is composed as an emitter and an absorber. The emitter sends the retarded wave and the absorber sends the advanced wave. The retarded wave of the emitter and the advanced wave of the absorber together produced the mutual energy current. We assume the current of emitter and the absorber all send half retarded wave and half advanced wave. The self-energy items are cancelled because the pure energy gain or loss are zero. In the microcosm self-energy items have no any contribution to the energy transfer of the photon. The self-energy current items of macrocosm are contribution of all mutual energy current of infinite photons.

In microcosm, the self-energy or the energy current corresponding to Pointing vector has no contribution to energy transfer. However, we have proven, if the mutual energy theorem established in microcosm for photon, the Poynting theorem is established also to macrocosm. We also obtain the equations photon should satisfy which is just the Maxwell equations. In this equations all self-energy items are all cancelled. From this equation we can find a solution in which the absorber is perpendicular to the emitter. The mutual energy current has two items which can be applied to interpret the line polarization / circle polarization and hence interpret the concept of spin of the photon. The above photon model is derived from electromagnetic field with Maxwell theory, but it is possible also suit the wave of other particles, for example electrons.

[1] J. A. Wheeler and R. P. Feynman, “Interaction with the absorber as the mechanism of radiation,” *Rev. Mod. Phys.*, vol. 17, p. 157, April 1945.

[2] J. A. Wheeler and R. P. Feynman, “Classical electrodynamics in terms of direct interparticle action,” *Rev. Mod. Phys.*, vol. 21, p. 425, July 1949.

[3] J. Cramer, “The transactional interpretation of quantum mechanics,” *Reviews of Modern Physics*, vol. 58, pp. 647–688, 1986.

[4] J. Cramer, “An overview of the transactional interpretation,” *International Journal of Theoretical Physics*, vol. 27, p. 227, 1988.

[5] J. Cramer, “The transactional interpretation of quantum mechanics and quantum nonlocality,” *https://arxiv.org/abs/1503.00039*, 2015.

[6] Mathematical Foundations of Quantum Theory, edited by A.R. Marlow, Academic Press, 1978. P, 39 lists seven experiments: double slit, microscope, split beam, tilt-teeth, radiation pattern, one-photon polarization, and polarization of paired photons.

[7] Walborn, S. P.; et al. (2002). "Double-Slit Quantum Eraser". Phys. Rev. A. 65 (3): 033818. arXiv:quant-ph/0106078Freely accessible. Bibcode:2002PhRvA..65c3818W. doi:10.1103/PhysRevA.65.033818.

[8] Yaron Bromberg, Ori Katz, Yaron Silberberg, Ghost imaging with a single detector, https://arxiv.org/abs/0812.2633, 2008

[9] S. ren Zhao, “The application of mutual energy theorem in expansion of radiation fields in spherical waves,” *ACTA Electronica Sinica, P.R. of China*, vol. 15, no. 3, pp. 88–93, 1987.

[10] S. Zhao, “The simplification of formulas of electromagnetic fields by using mutual energy formula,” *Journal of Electronics, P.R. of China*, vol. 11, no. 1, pp. 73–77, January 1989.

[11] S. Zhao, “The application of mutual energy formula in expansion of plane waves,” *Journal of Electronics, P. R. China*, vol. 11, no. 2, pp. 204–208, March 1989.

[12] S. ren Zhao, K. Yang, K. Yang, X. Yang, and X. Yang. (2015) The modified poynting theorem and the concept of mutual energy. [Online]. Available: http://arxiv.org/abs/1503.02006

[15]Shuang-ren Zhao, Kevin Yang, Kang Yang, Xingang Yang, Xintie Yang, The principle of the mutual energy, arXiv:1606.08710, 2016

[16]Shuang-ren Zhao, Kevin Yang, Kang Yang, Xingang Yang, Xintie Yang, The mutual energy current interpretation for quantum mechanics, arXiv:1608.08055, 2016