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

Shuang-ren Zhao, Kevin Yang, Kang Yang, Xingang Yang, (Imrecons Inc, London Ontario, Canada)

Xintie Yang (Aviation Academy, Northwestern Polytechnical University, Xi'an, China)

Abstract: In this article we will build the model of photon in time-domain. Study photon in the time domain is because the photon is a short time wave. In our 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. But we have proven that in the empty space the wave can been 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 is explanted. We studied the phenomenon of the wave function collapse. The total energy transfer can be divided as self-energy transfer and the mutual energy transfer. In our 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. Furthermore, we found the equation of photon should satisfy which is a modified from Maxwell equation. From this photon equation a solution of photon is found, in this solution the electric fields of emitter or absorber must parallel to the magnetic field. The current of absorber must perpendicular to the emitter. This way all self-energy items disappear. 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 our photon model.

Keyword: Photon, Quantum, Advanced wave, Retarded wave, Poynting theorem, mutual energy

## 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 author has introduced the mutual energy theory in 1987 [9-11]. Later the author 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 other quantum particles [13,14]. The above studies are 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.

The goal of this article is to build a model for photon, found 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 say infinite photon become light or electromagnetic field which should satisfy Maxwell equations. Hence Maxwell equations are a macrocosm field. In microcosm, only photon we are very difficult to think it still satisfies the Maxwell equations. We try to find the 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 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 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.

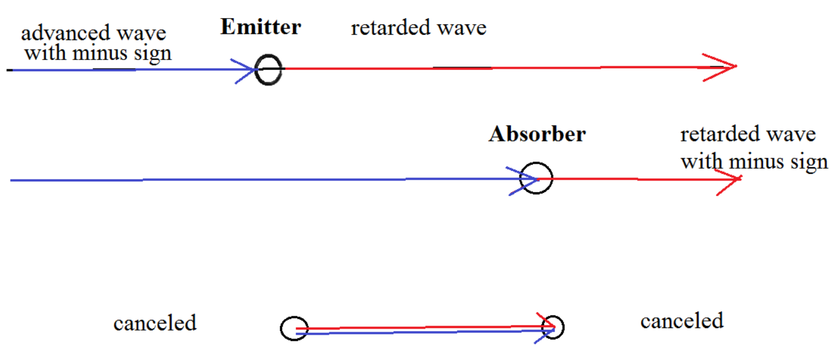


Figure 0. The Wheeler and Feynman model. The emitter sends retarded wave to right show as red arrow. The emitter sends advanced wave to the left which is blue. We have drawn the arrow in the opposite direction to the advanced wave. This is same to the absorber. However the retarded wave of the absorber 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 the in the region I and III the waves cancel and in the region II the waves reinforce.

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

(a) Why retarded wave is sent by the emitter to the positive direction and the advanced wave is sent to the negative direction? As I 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.

We endorse the absorber theory of Wheeler and Feynman. In this article we will introduce a 3D time-domain electromagnetic theory which suited 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, it is clear the field of the photon cannot fully satisfy the Maxwell equations. Because according Maxwell equation 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 equation is not 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)

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

Where $\boldsymbol{E}$ is the electric field. $\boldsymbol{H}$ is the magnetic H-field. $\boldsymbol{J}$ is the current intensity. $\Gamma$ 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 $\Gamma$. $\boldsymbol{u}$ is the electromagnetic field energy intensity. $\partial u$ is defined as

(2)

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

$\boldsymbol{D}=\boldsymbol{\epsilon}\boldsymbol{E}$ is the electric displacement, $\boldsymbol{B}=\boldsymbol{\mu}\boldsymbol{B}$ is magnetic B-field. $\partial u$ 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 loss of energy $\iiint_V (\boldsymbol{J}\cdot\boldsymbol{E})dV$ in the volume $V$ and increase of the energy inside the volume $\iiint_V (\partial\boldsymbol{u})\, dV$.

We assume the field as $\zeta = [\boldsymbol{E},\boldsymbol{H}]$ is electromagnetic field 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 wave.

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 the Poynting theorem contains nearly all 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 section.

# 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, but 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 $\boldsymbol{J_{1i}}, \boldsymbol{E_{1i}}$. 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 $\xi_{1i}$. $\boldsymbol{J}_{2\mathrm{i}}$ produces advanced wave $\xi_{2i}$.

Assume the total field is a superimposed field $\xi_i = \xi_{1i} + \xi_{2i}$, $\xi_1$ is retarded wave and $\xi_{2i}$ 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)

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

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.

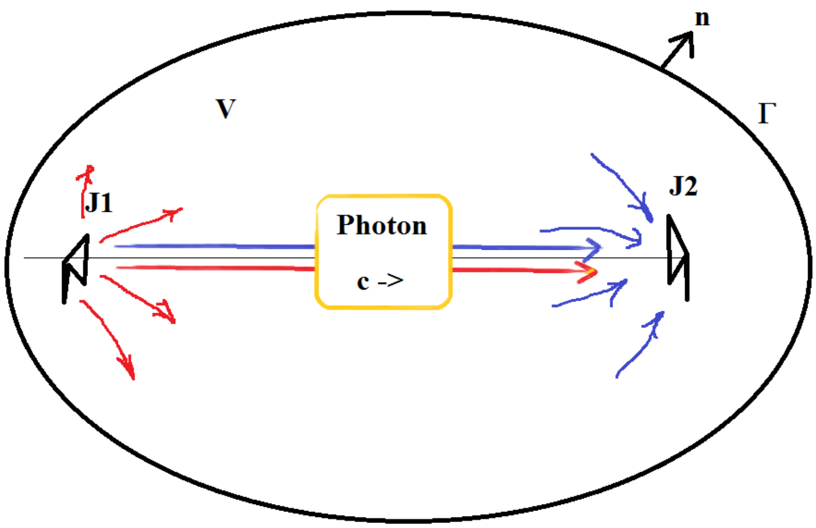


Figure 1. Photon model. There is an emitter and an absorber, emitter send retarded wave. The absorber sends advanced wave. The photon is sent out in $t = 0$, in short time $\Delta t$, hence photon is sent out from $t = 0$ to $\Delta t$, the photon has speed $c$. After a time $T$ it travels to distance $R = cT$, 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 absorber. This part energy current is diverged and sends 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 $\Gamma$, $\boldsymbol{\xi}_{1i}$ is no zero at a future time $T_\Gamma$ to $T_\Gamma + \Delta t$. $T_\Gamma = R/c$, where $c$ is light speed, $R$ is the distance from the emitter to the big sphere surface. $\Delta t$ 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 $\Gamma$ Hence the following integral vanishes ($\boldsymbol{\xi_{1i}}$ and $\boldsymbol{\xi_{2i}}$ are not nonzero in the same time, on the surface $\Gamma$). In the above calculation we have assume T is very small compared with $T_\Gamma$, hence we can write $T \to 0$. Hence we have,

(6)

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

We notice that the above formula is very important, that means the mutual energy cannot send energy 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 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 are different phase difference and perhaps cancel each other. Hence this part of energy current should not as 0, i.e.,

(8)

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

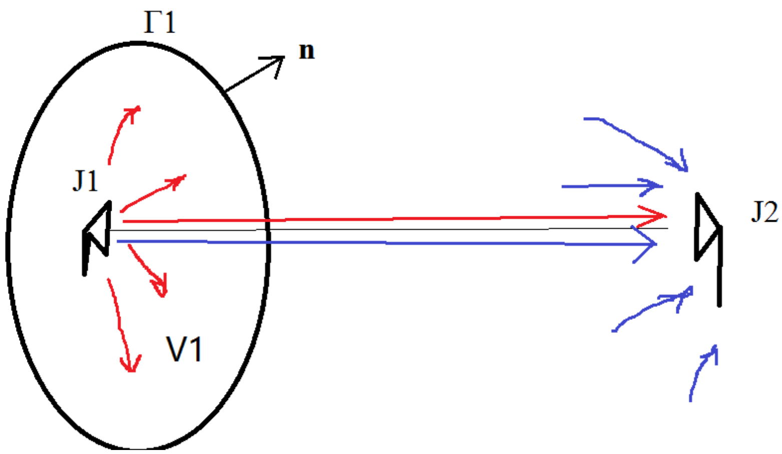


Figure 2., Red arrow is retarded wave, blue line is advanced wave. The arrow direction shows the direction of the energy current. The emitter contains inside the volume $V_1$. $\Gamma_1$ is the boundary surface of $V_1$. The energy current consist of the retarded wave and the advanced wave.

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)

$$-\oiint_{\Gamma_2} (\boldsymbol{E}_{1i} \times \boldsymbol{H}_{2i} + \boldsymbol{E}_{2i} \times \boldsymbol{H}_{1i}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_{V_2} (\boldsymbol{J}_{2i} \cdot \boldsymbol{E}_{1i}) dV$$

$$+ \iiint_{V_2} (\boldsymbol{E}_{1i} \cdot \partial \boldsymbol{D}_{2i} + \boldsymbol{E}_{2i} \cdot \partial \boldsymbol{D}_{1i} + \boldsymbol{H}_{2i} \partial \boldsymbol{B}_{1i} + \boldsymbol{H}_{2i} \partial \boldsymbol{B}_{1i}) dV$$

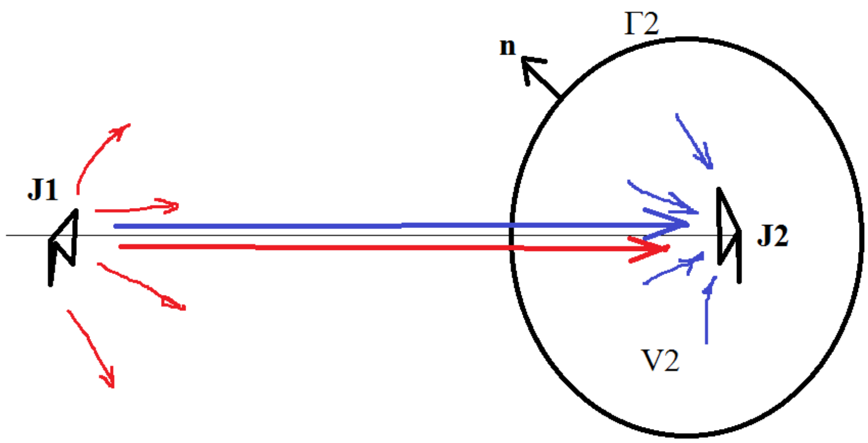


Figure 3. Choose the volume $V_2$ is close to the absorber. Red arrows are retarded wave, blue arrows are advanced wave. The direction of retarded wave is same as the direction of red arrow. The direction of advanced wave is at the opposite direction of the blue arrow. The arrow direction (red or blue)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

From the above discussion it is clear that,

I. $\oiint_{\Gamma} (\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}} + \boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}) \cdot \vec{\boldsymbol{n}} d\Gamma$ can be seen as energy current on the surface $\Gamma$ (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 $\epsilon$ and $\mu$ 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 tell us the all energy send out from $\Gamma_1$ are flow into (please notice the minus sign in the right) the surface $\Gamma_2$. Consider the surface $\Gamma_1$ and $\Gamma_2$ 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)

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

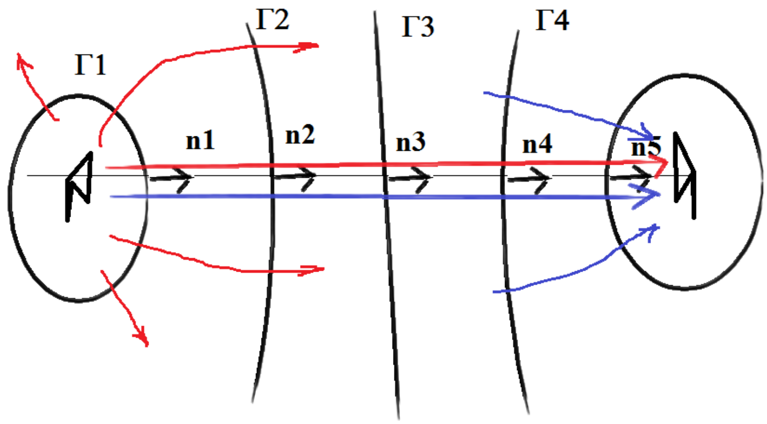


Figure 4. 5 surface is shown, the mutual energy current through each surface integral with time should be equal to each other.

From Figure 4 we can see that the time integral of the mutual energy current on an arbitrary surface are $\Gamma_i$ 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.

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 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.

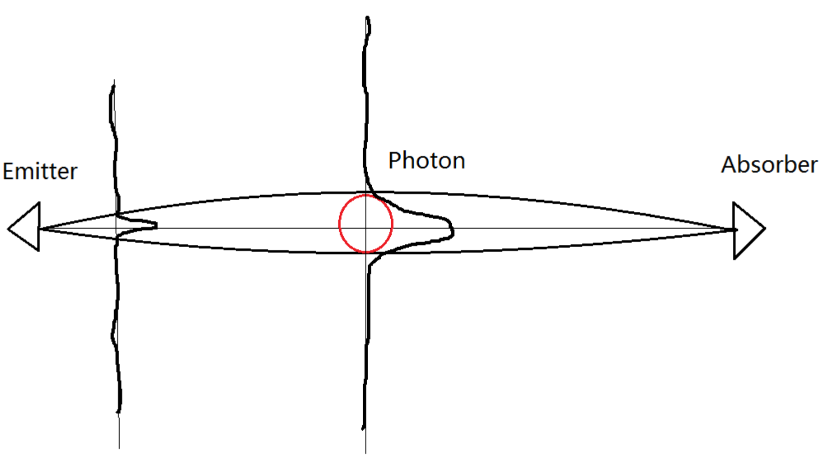


Figure 5. Photon in empty space, photon is just the mutual energy current. In a time photon is stayed at a place. This shows there is nothing about the concept of the wave function collapse.

## 5. The equation Photo should satisfy

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 photo 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 obtained.

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 part of wave in Eq.(3 and 4) is sent to infinite. However, we can assume

(a) The self-energy items vanish. This is because this 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 just throw this part of energy away.

(b) These 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. The retarded wave loss some energy, but the advanced wave gains the same amount of energy. This 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.

The idea of (b) 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. Now we apply it to the system with an emitter and an absorber, it 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 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. We can prove that from the idea (b) 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.

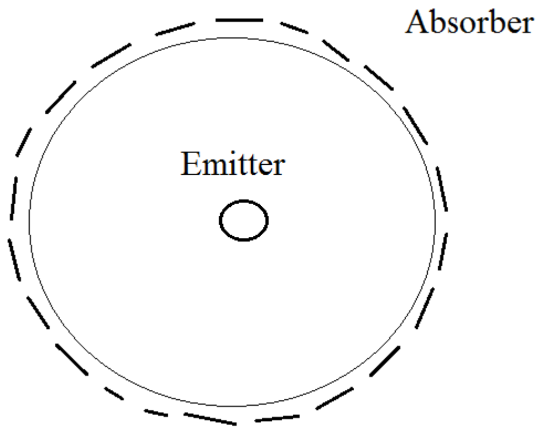


Figure 5. This shows emitters all at the center of the sphere. The absorbers are distributed at the surface of the sphere. The absorber is the environment. We assume the absorbers are surrounded the emitter. This is our simplified macrocosm model.

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)

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

(17)

$$-\oint\!\!\!\oint_{\Gamma} (\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}}) \cdot \vec{\boldsymbol{n}} d\Gamma = \iiint_V (\mathrm{J}_{2i} \cdot \boldsymbol{E_{2i}} + \partial u_{\boldsymbol{2i}}) dV$$

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

(18)

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

$$+\iiint_V (\boldsymbol{E}_{1i} \cdot \partial \boldsymbol{D}_{2i} + \boldsymbol{E}_{2i} \cdot \partial \boldsymbol{D}_{1i} + \boldsymbol{H}_{2i} \partial \boldsymbol{B}_{1i} + \boldsymbol{H}_2 \partial \boldsymbol{B}_{1i}) dV$$

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)**

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

$$= (\sum_{\boldsymbol{i}} \boldsymbol{E}_{1i} + \sum_j \boldsymbol{E}_{2j}) \times (\sum_{\boldsymbol{m}} \boldsymbol{H}_{1m} + \sum_{\boldsymbol{n}} \boldsymbol{H}_{2n})$$

$$= \sum_{\boldsymbol{i}} \boldsymbol{E}_{1i} \times \sum_{\boldsymbol{m}} \boldsymbol{H}_{1m} + \sum_{\boldsymbol{i}} \boldsymbol{E}_{1i} \times \sum_{\boldsymbol{n}} \boldsymbol{H}_{2n} + \sum_j \boldsymbol{E}_{2j} \times \sum_{\boldsymbol{m}} \boldsymbol{H}_{1m} + \sum_{\boldsymbol{j}} \boldsymbol{E}_{2j} \times \sum_{\boldsymbol{n}} \boldsymbol{H}_{2n}$$

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)**

$$\sum_{\boldsymbol{i}} \boldsymbol{E}_{1i} \times \sum_{\boldsymbol{m}} \boldsymbol{H}_{1m} = \sum_{\boldsymbol{im}} \boldsymbol{E}_{1i} \times \boldsymbol{H}_{1m} = \sum_{\boldsymbol{i}} \boldsymbol{E}_{1i} \times \boldsymbol{H}_{1i}$$

In the above, considering $\boldsymbol{E}_{1i} \times \boldsymbol{H}_{1m} = \boldsymbol{0}, \boldsymbol{if}\ \boldsymbol{i} \neq \boldsymbol{m}.$ 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)

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

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

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)

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

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

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.

**(2) Assume self energy vanishes**

In this situation all self-energy items vanish. If self-energy current is existent, we have to assume it sends to infinity and reflect at infinity and become advanced wave of the absorber. If the energy of photon is transferred through this wave, 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 is not existent. We will study that if there is only mutual energy current what will happen.

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,

(27)

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

$$=\iiint_{V}\sum_{i}(\boldsymbol{J_{1i}}\cdot\boldsymbol{E_{2i}})dV+\iiint_{V}\sum_{i}(\boldsymbol{J_{2i}}\cdot\boldsymbol{E_{1i}})dV$$

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

We assume the field of emitter $\boldsymbol{J_{1i}}$ can only be received by the absorber $\boldsymbol{J_{2i}}$, 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, considering

(28) $\boldsymbol{E_{1i}}\times\boldsymbol{H_{2j}} = 0 \quad if\ i \neq j$

(29) $\boldsymbol{E_{2i}}\times\boldsymbol{H_{1j}} = 0 \quad if\ i \neq j$

(30) $\boldsymbol{J_{1i}}\times\boldsymbol{E_{2j}} = 0 \quad if\ i \neq j$

Hence, there is

(31)

$$\sum_i \boldsymbol{E_{1i}}\times\boldsymbol{H_{2i}} = \sum_i \boldsymbol{E_{1i}}\times\sum_j \boldsymbol{H_{2j}} = \boldsymbol{E_1}\times\boldsymbol{H_2}$$

Assume $\boldsymbol{J_1} = \sum_i \boldsymbol{J_{1i}}$ and $\boldsymbol{J_2} = \sum_j \boldsymbol{J_{2j}}$, $\boldsymbol{E_1} = \sum_i \boldsymbol{E_{1i}}$, $\boldsymbol{E_2} = \sum_i \boldsymbol{E_{2i}}$, consider Eq.(31) the Eq.(27) becomes

(32)

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

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

We assume all the advanced waves average should close to the retarded wave that is,

(32)

$$\sum_i \boldsymbol{E_{1i}} = \sum_i \boldsymbol{E_{2i}} \equiv \frac{\boldsymbol{1}}{\boldsymbol{2}}\boldsymbol{E}$$

$$\sum_i \boldsymbol{H_{1i}} = \sum_i \boldsymbol{H_{2i}} \equiv \frac{\boldsymbol{1}}{\boldsymbol{2}}\boldsymbol{H}$$

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,

(33)

$$\frac{\boldsymbol{1}}{\boldsymbol{4}}\oiint_\Gamma (\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma = \frac{\boldsymbol{1}}{\boldsymbol{2}}\iiint_V (\boldsymbol{J_1}\cdot\boldsymbol{E})dV + \frac{\boldsymbol{1}}{\boldsymbol{2}}\iiint_V (\boldsymbol{J_2}\cdot\boldsymbol{E})dV$$

$$+\frac{\mathbf{1}}{\mathbf{4}}\iiint_V (\boldsymbol{E}\cdot\partial\boldsymbol{D}+\boldsymbol{H}\cdot\partial\boldsymbol{B})dV$$

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,

(34)

$$-\iiint_{V_1}(\boldsymbol{J_1}\cdot\boldsymbol{E})dV=\frac{\mathbf{1}}{\mathbf{2}}[\oiint_{\Gamma_1}(\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma+\iiint_{V_1}(\boldsymbol{E}\cdot\partial\boldsymbol{D}+\boldsymbol{H}\cdot\partial\boldsymbol{B})dV]$$

Comparing to Poynting theorem Eq.(26), the above formula equal sign actually did not established. The right side is only has half value of the left side. The reason of the above formula is clear, we have thrown away the self-energy items, $\iiint_V (\boldsymbol{J_{1i}}\cdot\boldsymbol{E_{1i}})dV$ and $\iiint_V (\boldsymbol{J_{2i}}\cdot\boldsymbol{E_{2i}})dV$ and so on. $\oiint_{\Gamma_1}(\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma$ is energy current. $\frac{\mathbf{1}}{\mathbf{2}}[\oiint_{\Gamma_1}(\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma$ means the we only obtained half the mutual energy current it should be.

$\boldsymbol{J_1}=\sum_{\boldsymbol{i}} \boldsymbol{J_{1i}}$, is the current of the emitter, we actually do not know it's exactly value. We can make the replacement, $\boldsymbol{J_1}\leftarrow\frac{1}{2}\boldsymbol{J_1}$. This means that we have used $\frac{1}{2}\boldsymbol{J_1}$ to replace $\boldsymbol{J_1}$. Actually this is also because the energy transferred by self-energy part Eq.(3 and 4) must be replaced by the transfer of the mutual energy current. We can say the energy transfer with mutual energy has taken over the transfer of the self-energy. We can also say transfer with the self-energy collapse to the transfer with mutual energy. Any way we can say to the photon the mutual energy theorem can be established which consider the fact 2, Eq.(3-5) becomes,

(35)

$$-\oiint_\Gamma (\boldsymbol{E_{1i}}\times\boldsymbol{H_{1i}})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_V (\mathbf{J_{1i}}\cdot\boldsymbol{E_{1i}}+\partial u_{\mathbf{1}\boldsymbol{i}})dV=0$$

(36)

$$-\oiint_\Gamma (\boldsymbol{E_{2i}}\times\boldsymbol{H_{2i}})\cdot\vec{\boldsymbol{n}}d\Gamma=\iiint_V (\mathrm{J}_{2i}\cdot\boldsymbol{E_{2i}}+\partial u_{\mathbf{2}\boldsymbol{i}})dV=0$$

(37)

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

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

According above discussion, if we assume the above formula established, Eq.(34) can be replaced as

(38)

$$-\iiint_{V_1}(\boldsymbol{J_1}\cdot\boldsymbol{E})dV=[\oiint_{\Gamma_1}(\boldsymbol{E}\times\boldsymbol{H})\cdot\vec{\boldsymbol{n}}d\Gamma+\iiint_{V_1}(\boldsymbol{E}\cdot\partial\boldsymbol{D}+\boldsymbol{H}\cdot\partial\boldsymbol{B})dV]$$

This means even we assume the energy transfer of photon is only through mutual energy current, the self-energy doesn't have any contributions, we still can obtain Poynting theorem in macrocosm.

Eq.(35-36) are the self-energy items, if these items are vanished, as compensation we have to double the mutual energy current in microcosm. This way we can still keep the Poynting theorem is established in macrocosm.

We have proven that all reciprocity theorem can be proven from Poynting theorem [12], we also know the Green function solution of Maxwell equation can also be obtained from Lorentz reciprocity theorem. Maxwell equation cannot be derived from their solution, but Maxwell equations should be possible to be obtained from their solution by induction.

Hence we can say for photon (for microcosm) there is only the mutual energy theorem to be established. In microcosm the all self-energy items are all vanish. The Poynting theorem corresponding to the self-energy items are all vanish in both side of Poynting theorem. However, the adjusted mutual energy theorem (please notice the factor 2 in the formula) still established. The above derivation tells us that the macrocosm the Poynting theorem is established and hence the Maxwell equations can also be established. This means in microcosm the mutual energy theorem is more fundamental than Poynting theorem. Hence we can think it is a principle: the mutual energy principle. We can start from the Mutual energy principle in microcosm to obtain the Poynting theorem and hence also the Maxwell equations of macrocosm.

We can further assume that the mutual energy principle is established also for all other particles of the whole quantum mechanics.

**(3) Summary**

In this section we have introduced two methods to deal with the self-energy items of the transfer of the energy. 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 is not at infinite empty space but inside a metal container, we still have to assume the self-energy items can send to infinity, this seems doesn't possible. Hence we make another assumption. Another is that the transfer of self-energy doesn't existent or self-energy items are taken over by the transfer of the mutual energy current. We also can say that the self-energy items collapse to the mutual energy current. The mutual energy current is the only one which can transfer the energy in microcosm. In this case the mutual energy current has to be adjusted by a fact 2. Both view of points are very good and could be acceptable. And we trend to the concept that the self-energy doesn't transfer any energy and hence the mutual energy current is the only one which can transfer the energy.

The above both view of points are much better than assume there is no advanced wave, in which if the absorber need to receive energy, the only possibility is all the energy is collapse to the absorber. We can also not derive macrocosm Poynting theorem from microcosm photon model.

J. Crammer introduced the concept of continually collapse that means 3D wave continually collapse to a 1-D wave [3-5]. In our mutual energy current theory, the energy transfer is also very close to a 1-D wave. The transferred energy current in any surface is same. The self-energy current collapse to the mutual energy current that is also very easy to be understand. If we assume the energy of photon are composed by small parts, it is clear there should be some binding force between them, we do not know this force. But this force makes the energy current transferred from emitter to the absorber instead send energy to the whole space. That is reason we assume the self-energy items collapse to the mutual energy current. Hence there is only mutual energy current for photon. The mutual energy current is composed with the advanced wave of absorber and the retarded wave of the emitter.

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 does not need any more in our photon model.

This section tells us, if photon are composed as an emitter and an absorber, and the emitter send retarded wave and the absorber send advanced wave, and photo satisfy mutual energy theorem (adjusted by a factor 2 for the mutual energy current), 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).

# 6. The photon equations

In the above we obtain the conclusion that photon should satisfy the mutual energy theorem formula, and self-energy items vanishes. This section let us found the equation photon should satisfy.

For the emitter and the absorber of the photon, we assume the field of absorber and emitter together satisfy some equations, which can derive the above mutual energy principle.

$$\zeta_i = \zeta_{1i} + \zeta_{2i} \tag{39}$$

where $\zeta_{1i} = [\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$, which is produced by the emitter where $\zeta_{2i} = [\boldsymbol{E}_{2i}, \boldsymbol{H}_{2i}]$, where $\zeta_{1i} = [\boldsymbol{E}_{1i}, \boldsymbol{H}_{1i}]$, the above superimposition is

$$\nabla \times (\boldsymbol{E}_{1i} + \boldsymbol{E}_{2i}) = -\partial(\boldsymbol{B}_{1i} + \boldsymbol{B}_{2i}) \tag{40}$$

$$\nabla \times (\boldsymbol{H}_{1i} + \boldsymbol{H}_{2i}) = \frac{1}{2}(\boldsymbol{J}_{1i} + \boldsymbol{J}_{2i}) + \partial(\boldsymbol{D}_{1i} + \boldsymbol{D}_{2i}) \tag{41}$$

(42)

$$\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}} = 0$$
$$\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{2i}} = 0$$

$$\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \boldsymbol{0}$$
$$\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}} = \boldsymbol{0}$$

We can derive Eq.(37) from above group equations. The above equation can be seen as photon's equations, which is very close to Maxwell equations, but the field of photon must put the field of emitter and absorber together. All self-field items are assumed to be vanished. There are a factor 2 (or $\frac{\mathbf{1}}{\mathbf{2}}$) which is applied to compensate the vanished items of all the self-energy items.

In quantum physics, there is also the renormalization and Regularization process to deal with the infinity. Here we throw away the self-energy item perhaps because the same reason. Since there is mutual energy current, that allow us to throw away the self-energy items without big influence to the field or equations of macrocosm.

Proof:

First from self-energy Poynting theorem Eq.(16,17) and considering Eq(42) we obtain,

(43)

$$\boldsymbol{E}_{1i} \cdot \partial \boldsymbol{D_{1i}} = \boldsymbol{0}$$
$$\boldsymbol{E}_{2i} \cdot \partial \boldsymbol{D_{2i}} = \boldsymbol{0}$$

Assume that

**(44)**

$$\boldsymbol{E_i} = \boldsymbol{E_{1i}} + \boldsymbol{E_{2i}}$$
$$\boldsymbol{H_i} = \boldsymbol{H_{1i}} + \boldsymbol{H_{2i}}$$
$$\boldsymbol{J_i} = \boldsymbol{J_{1i}} + \boldsymbol{J_{2i}}$$
$$\boldsymbol{D_i} = \boldsymbol{D_{1i}} + \boldsymbol{D_{2i}}$$
$$\boldsymbol{B_i} = \boldsymbol{B_{1i}} + \boldsymbol{B_{2i}}$$

We have the following equations,

(45)

$$\boldsymbol{\nabla} \times \boldsymbol{E_i} = -\partial \boldsymbol{B_i}$$
$$\boldsymbol{\nabla} \times \boldsymbol{H_i} = \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{J_i} + \partial \boldsymbol{D_i}$$

Hence, we have

(46)

$$-\boldsymbol{\nabla}\cdot(\boldsymbol{E}_i\times\boldsymbol{H}_i)$$
$$=-(\boldsymbol{\nabla}\times\boldsymbol{E}_i\cdot\boldsymbol{H}_i-\boldsymbol{E}_i\cdot\boldsymbol{\nabla}\times\boldsymbol{H}_i)$$
$$=-(-\partial\boldsymbol{B}_i\cdot\boldsymbol{H}_i-\boldsymbol{E}_i\cdot\left(\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{J}_i+\partial\boldsymbol{D}_i\right))$$
$$=\boldsymbol{H}_i\cdot\partial\boldsymbol{B}_i+\boldsymbol{E}_i\cdot\partial\boldsymbol{D}_i+\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{J}_i\boldsymbol{E}_i$$

Thant is we have,

(47)

$$-\boldsymbol{\nabla}\cdot(\boldsymbol{E}_i\times\boldsymbol{H}_i)=\boldsymbol{H}_i\cdot\partial\boldsymbol{B}_i+\boldsymbol{E}_i\cdot\partial\boldsymbol{D}_i+\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{J}_i\cdot\boldsymbol{E}_i$$

Or considering Eq.(44) we have

(48)

$$-\boldsymbol{\nabla}\cdot((\boldsymbol{E}_{1i}+\boldsymbol{E}_{2i})\times(\boldsymbol{H}_{1i}+\boldsymbol{H}_{2i}))$$
$$=(\boldsymbol{H}_{1i}+\boldsymbol{H}_{2i})\cdot\partial(\boldsymbol{B}_{1i}+\boldsymbol{B}_{2i})+(\boldsymbol{E}_{1i}+\boldsymbol{E}_{2i})\cdot\partial(\boldsymbol{D}_{1i}+\boldsymbol{D}_{2i})$$
$$+\frac{\mathbf{1}}{\mathbf{2}}(\boldsymbol{J}_{1i}+\boldsymbol{J}_{2i})\cdot(\boldsymbol{E}_{i1}+\boldsymbol{E}_{i2})$$

Or considering Eq.(42,43) we obtain,

(49)

$$-\boldsymbol{\nabla}\cdot(\boldsymbol{E}_{1i}\times\boldsymbol{H}_{2i}+\boldsymbol{E}_{2i}\times\boldsymbol{H}_{1i})$$
$$=\boldsymbol{H}_{1i}\cdot\partial\boldsymbol{B}_{2i}+\boldsymbol{H}_{2i}\cdot\partial\boldsymbol{B}_{1i}+\boldsymbol{E}_{1i}\cdot\partial\boldsymbol{D}_{2i}+\boldsymbol{E}_{2i}\cdot\partial\boldsymbol{D}_{1i}$$
$$+\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{J}_{1i}\cdot\boldsymbol{E}_{i2}+\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{J}_{2i}\cdot\boldsymbol{E}_{i1}$$

Or make an integral to the above equation we have,

(50)

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

This is the Eq.(37). We have obtained the adjusted mutual energy theorem from the equation photon should satisfy.

Here we have not assume that the wave of emitter and the wave of absorber satisfy Maxwell equations separately. The reason of that is in that case Maxwell equation has the solution, when we add the condition of the self-energy items vanish, perhaps can produce a zero solution which is not we want.

## 7. Find a solution to the above photon equations

In this section we will try to find a special solution which satisfies the above equations. We do not try to find all solutions and we only show one solution in which can be the photon model. From $\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \boldsymbol{0}$, We know that the filed, $\boldsymbol{E_{1i}}||\boldsymbol{H_{1i}}$, here " ||" means "parallel to", we can assume

(51)

$$\boldsymbol{E_{1i}} = K_1\boldsymbol{H_{1i}}$$
$$\boldsymbol{E_{2i}} = K_2\boldsymbol{H_{2i}}$$

$K_1, K_2$ are constants and can have positive value and negative values. We assume the current of the absorber is perpendicular to the current of the emitter for example,

**(52)**

$$\boldsymbol{J_{1i}} = \delta(x)\delta(y)\delta(z)\vec{\boldsymbol{z}}$$

$$\boldsymbol{J_{2i}} = \delta(x-d)\delta(y)\delta(z)\vec{\boldsymbol{y}}$$

$\vec{\boldsymbol{z}}$ is unit vector in z axis direction. $\vec{\boldsymbol{y}}$ is unit vector in $z$ axis direction. $d$ is the distance between the emitter and the absorber. $\delta(\cdot)$ is delta function. We assume the magnetic field still can be obtained with the right hand rule. We can assume for the emitter the constant $K_1$ is positive, for simple we can just take $K_1 = 1$ (here we omit the scale value and the unit), hence the electric field $\boldsymbol{E_{1i}} = \boldsymbol{H_{1i}}$ is in the same direction of magnetic field. We assume, for the absorber we assume that $\boldsymbol{E_{2i}} = -\boldsymbol{H_{2i}}$. In the last few section we have shown that the energy current of the photon is close to a one dimensional wave, even it actually a 3D wave. The most energy current is go through along the line from the emitter to the absorber. Hence here we only study the situation of the fields in which the energy current go along the line liked the absorber to the emitter. We can see in the Figure 6. In this situation the direction of $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ and $\boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}$ are all in the direction of $\vec{\boldsymbol{x}}$ which is just the direction from emitter to the absorber.

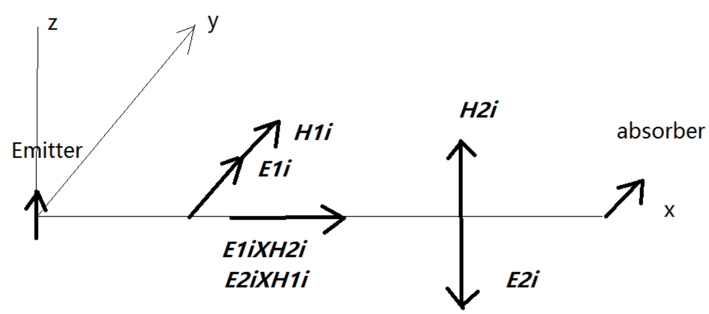


Figure 6. The current of the emitter is perpendicular to the current of the absorber. The filed of $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ and $\boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}$ has the same direction as the radiation direction which is from the emitter to the absorber. We have assume $\boldsymbol{E_{1i}} = \boldsymbol{H_{1i}}, \boldsymbol{E_{2i}} = -\boldsymbol{H_{2i}}$.

Since we have assume the $\boldsymbol{E_{1i}}||\boldsymbol{H_{1i}}$, this also guarantee that $\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}} = 0$. $\boldsymbol{E_{2i}}||\boldsymbol{H_{2i}}$, this also guarantee that $\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{2i}} = 0$.

$\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \boldsymbol{0}$, $\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}} = \boldsymbol{0}$, further guarantees $\boldsymbol{E}_{1i} \cdot \partial \boldsymbol{D_{1i}}$ through the Poynting theorem Eq.(3). Similarly $\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}} = \boldsymbol{0}$, $\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{2i}} = \boldsymbol{0}$ further guarantees $\boldsymbol{E}_{2i} \cdot \partial \boldsymbol{D_{2i}}$ through the Poynting theorem Eq.(4). Hence in the above example all self-energy items all vanished. To the absorber is also same all self energy items are all vanish.

Electric field of emitter is parallel to their magnetic field. The Electric field of the absorber is also parallel to their magnetic field, which will make the self-energy items all vanish, hence there are only mutual energy items left. This will guarantee the mutual current is the only one can transfer energy.

# 8. Polarization and spin of the photon

In the mutual energy current

(53)

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

there are two items, $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ 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 has 90 degree in phase difference, we will obtain a circular polarized field.

Originally in the time the author write other article [15,16], he has thought that the circle polarization or spin is because of 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. He 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 by coincidence. It is interesting to notice this two items $\boldsymbol{E_{1i}} \times \boldsymbol{H_{2i}}$ and $\boldsymbol{E_{2i}} \times \boldsymbol{H_{1i}}$ 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.

Up to now, the photon model is very clear. The current of the absorber must perpendicular to the current of the emitter. The electric field of the absorber and emitter mast parallel to their magnetic field and this guarantee the self-energy items disappear. The mutual energy current offer two items which can interpret the photon polarization or photon spin.

From this photon model, the spin and polarization of photon is not only related to the emitter but also the absorber, this can offer a good interpretation to the delayed choice experiment of J. A. Wheeler [6].

# 9. The field equation of the field again

Eq.(42) $\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \mathbf{0}$ actually tell us $\boldsymbol{E_{1i}}$ cannot be produced by $\boldsymbol{H_{1i}}$ and $\boldsymbol{H_{1i}}$ cannot be produced by $\boldsymbol{E_{1i}}$. $\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}} = \mathbf{0}$ actually tell us $\boldsymbol{E_{2i}}$ cannot be produced by $\boldsymbol{H_{2i}}$ and $\boldsymbol{H_{2i}}$ cannot be produced by $\boldsymbol{E_{2i}}$. Hence we can simply the equations Eq.(41,42) as

(54)

$$\nabla \times \boldsymbol{E_{1i}} = -\partial \boldsymbol{B_{2i}}$$

$$\nabla \times \boldsymbol{E_{2i}} = -\partial \boldsymbol{B_{1i}}$$

$$\nabla \times \boldsymbol{H_{1i}} = \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{J_{1i}} + \partial \boldsymbol{D_{2i}}$$

$$\nabla \times \boldsymbol{H_{2i}} = \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{J_{2i}} + \partial \boldsymbol{D_{1i}}$$

Considering Eq.(54) can derive the Eq.(40,41), but it still cannot derive the Eq.(42), Eq.(42) should be include as photon equations. Hence we rewrite it here,

(55)

$$\boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}} = 0$$

$$\boldsymbol{J_{2i}} \cdot \boldsymbol{E_{2i}} = 0$$

$$\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \mathbf{0}$$

$$\boldsymbol{E_{2i}} \times \boldsymbol{H_{2i}} = \mathbf{0}$$

$\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}} = \mathbf{0}$ is too severe. Actually we need only

$$\nabla \cdot (\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}) = \mathbf{0}$$

which is the self energy current should be zero and which in turn have,

$$\nabla \cdot (\boldsymbol{E_{1i}} \times \boldsymbol{H_{1i}}) = \nabla \times \boldsymbol{E_{1i}} \cdot \boldsymbol{H_{1i}} - \nabla \times \boldsymbol{H_{1i}} \cdot \boldsymbol{E_{1i}}$$

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

$$= -\partial \boldsymbol{B_{2i}} \cdot \boldsymbol{H_{1i}} - \partial \boldsymbol{D_{2i}} \cdot \boldsymbol{E_{1i}} - \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}}$$

$$= -\mu \partial \boldsymbol{H_{2i}} \cdot \boldsymbol{H_{1i}} - \epsilon \partial \boldsymbol{E_{2i}} \cdot \boldsymbol{E_{1i}} - \frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{J_{1i}} \cdot \boldsymbol{E_{1i}}$$

$$\boldsymbol{H_{2i}} \perp \boldsymbol{H_{1i}}$$

$$\boldsymbol{E_{2i}} \perp \boldsymbol{E_{1i}}$$

$$\boldsymbol{J_{1i}} \perp \boldsymbol{E_{1i}}$$

Eq.(54,55) can be seen as photon equations. All field of the photon should be possible to be solved from them.

From these equations we known that the fields of absorber and emitter are not independent to each other. Their fields communicate to each other. These communicated field can be referred as coupled fields. The photon energy is also transferred by mutual energy current. The mutual energy current to the emitter it is retarded wave. The mutual energy current to the absorber it is advanced field. But mutual energy current itself is actually not only retarded wave and also not only advanced wave. It just a wave transferred from emitter to the absorber. This energy doesn't go to infinite empty space. The field only transfer the energy from emitter to the absorber. This energy transfer looks similar to the water go through a pipe. The wave doesn't collapse.

# 10. Derive the macrocosm Maxwell equations from the microcosm photon equations

In last section we have obtain the Photon equations in microcosm. Now we try to obtain the Maxwell equations in macrocosm. From Equation Eq.(44) we can obtain Eq.(40,41). The summation of all fields of the photon becomes,

(56)

$$\sum_{i} \nabla \times (\boldsymbol{E}_{1i} + \boldsymbol{E}_{2i}) = \sum_{i} -\partial(\boldsymbol{B}_{1i} + \boldsymbol{B}_{2i})$$

$$\sum_{i} \nabla \times (\boldsymbol{H}_{1i} + \boldsymbol{H}_{2i}) = \sum_{i} \frac{1}{2}(\boldsymbol{J}_{1i} + \boldsymbol{J}_{2i}) + \partial(\boldsymbol{D}_{1i} + \boldsymbol{D}_{2i})$$

Consider that the retarded macrocosm fields of all emitters can be obtain by

(57)

$$\boldsymbol{J}_1 = \sum_{i} \boldsymbol{J}_{1i}$$

$$\boldsymbol{E}_1 = \sum_{i} \boldsymbol{E}_{1i}$$

$$\boldsymbol{H}_1 = \sum_{i} \boldsymbol{E}_{1i}$$

$$\boldsymbol{D}_1 = \sum_{i} \boldsymbol{D}_{1i}$$

$$\boldsymbol{B}_1 = \sum_{i} \boldsymbol{B}_{1i}$$

And the advanced field of the absorber can be obtained,

(58)

$$\boldsymbol{J}_2 = \sum_i \boldsymbol{J}_{2i}$$

$$\boldsymbol{E}_2 = \sum_i \boldsymbol{E}_{2i}$$

$$\boldsymbol{H}_2 = \sum_i \boldsymbol{E}_{2i}$$

$$\boldsymbol{D}_2 = \sum_i \boldsymbol{D}_{2i}$$

$$\boldsymbol{B}_2 = \sum_i \boldsymbol{B}_{2i}$$

We obtain,

(59)

$$\nabla \times (\boldsymbol{E}_1 + \boldsymbol{E}_2) = -\partial(\boldsymbol{B}_1 + \boldsymbol{B}_2)$$

$$\nabla \times (\boldsymbol{H}_1 + \boldsymbol{H}_2) = \frac{1}{2}(\boldsymbol{J}_1 + \boldsymbol{J}_2) + \partial(\boldsymbol{D}_1 + \boldsymbol{D}_2)$$

For the macrocosm field we can not distinguish the field is advanced field or it is retarded field hence there is the

We obtain,

(60)

$$\boldsymbol{E} = \boldsymbol{E}_1 + \boldsymbol{E}_2$$

$$\boldsymbol{H} = \boldsymbol{H}_1 + \boldsymbol{H}_2$$

$$\boldsymbol{D} = \boldsymbol{D}_1 + \boldsymbol{D}_2$$

$$\boldsymbol{B} = \boldsymbol{B}_1 + \boldsymbol{B}_2$$

Considering Eq.(60), Eq.(59) can be written as,

**(61)**

$$\nabla \times \boldsymbol{E} = -\partial \boldsymbol{B}$$

$$\nabla \times \boldsymbol{H} = \frac{1}{2}(\boldsymbol{J}_1 + \boldsymbol{J}_2) + \partial \boldsymbol{D}$$

The above equations have two sources $\boldsymbol{J_1}$ and $\boldsymbol{J_2}$. Since the above equation is linear, we can rewrite it as two equations and obtain two solutions. The summation of solution of following equations is the solution of the above equation.

(62)

$$\nabla \times \boldsymbol{E_I} = -\partial \boldsymbol{B_I}$$

$$\nabla \times \boldsymbol{H_I} = \frac{1}{2}\boldsymbol{J_1} + \partial \boldsymbol{D_I}$$

**(63)**

$$\nabla \times \boldsymbol{E_{II}} = -\partial \boldsymbol{B_{II}}$$

$$\nabla \times \boldsymbol{H_{II}} = \frac{1}{2}\boldsymbol{J_2} + \partial \boldsymbol{D_{II}}$$

The solution of Eq.(62) is written as $\boldsymbol{E_I}, \boldsymbol{H_I}, \boldsymbol{D_I}, \boldsymbol{B_I}$, assume $\boldsymbol{E_I}, \boldsymbol{H_I}, \boldsymbol{D_I}, \boldsymbol{B_I}$ this is retarded wave.

Eq.(63) can be written as $\boldsymbol{E_{II}}, \boldsymbol{H_{II}}, \boldsymbol{D_{II}}, \boldsymbol{B_{II}}$**.** Assume $\boldsymbol{E_{II}}, \boldsymbol{H_{II}}, \boldsymbol{D_{II}}, \boldsymbol{B_{II}}$ is advanced field. We must notice that $\boldsymbol{E_I}$ is not same as $\boldsymbol{E_1}$ and $\boldsymbol{E_{II}}$ is not same as $\boldsymbol{E_2}$. $\boldsymbol{E_1}$ and $\boldsymbol{E_2}$ are sum of microcosm fields**.** Which are filed coupled fields. $\boldsymbol{E_2}$. $\boldsymbol{E_1}$ are all produced by current $\boldsymbol{J_1}$ and $\boldsymbol{J_2}$ together. $\boldsymbol{E_I}$ and $\boldsymbol{E_{II}}$ are uncoupled fields. $\boldsymbol{E_I}$ only relate to $\boldsymbol{J_1}$**.** $\boldsymbol{E_{II}}$ is only relate to $\boldsymbol{J_2}$.

$\boldsymbol{E_I}$ is retarded wave in macrocosm. $\boldsymbol{E_{II}}$ advanced wave is the field of environment. We have side in macrocosm these two field are equal to each other and hence there is,

(64)

$$\boldsymbol{E_I} = \boldsymbol{E_{II}} = \frac{1}{2}\boldsymbol{E}$$

$$\boldsymbol{H_I} = \boldsymbol{H_{II}} = \frac{1}{2}\boldsymbol{H}$$

$$\boldsymbol{D_I} = \boldsymbol{D_{II}} = \frac{1}{2}\boldsymbol{D}$$

$$\boldsymbol{B_I} = \boldsymbol{B_{II}} = \frac{1}{2}\boldsymbol{B}$$

Substituting Eq.(65) to Eq.(63), we obtain**,**

**(65)**

$$\nabla \times \boldsymbol{E} = -\partial \boldsymbol{B}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J_1} + \partial \boldsymbol{D}$$

Or

(66)

$$\nabla \times \boldsymbol{E} = -\partial \boldsymbol{B}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J_2} + \partial \boldsymbol{D}$$

Eq.(65) is the Maxwell equations. Eq.(66) is redundant to the macrocosm and hence can be omitted. This proves our microcosm photon equations con derive the macrocosm Maxwell equations.

## 11. Further study the photon equation

(67)

$$\nabla \times \boldsymbol{E}_{1i} = -\partial \boldsymbol{B}_{2i}$$

$$\nabla \times \boldsymbol{E}_{2i} = -\partial \boldsymbol{B}_{1i}$$

$$\nabla \times \boldsymbol{H}_{1i} = \frac{1}{2}\boldsymbol{J}_{1i} + \partial \boldsymbol{D}_{2i}$$

$$\nabla \times \boldsymbol{H}_{2i} = \frac{1}{2}\boldsymbol{J}_{2i} + \partial \boldsymbol{D}_{1i}$$

Equations Eq(67) can derive the photon equation Eq.(54). We can assume Eq.(67) is the real possible photon equations. Let us find the solution of Eq.(67).

**(68)**

$$\nabla \times \boldsymbol{E}_{1i} = -\mu\partial \boldsymbol{H}_{2i}$$

$$\nabla \times \boldsymbol{E}_{2i} = -\mu\partial \boldsymbol{H}_{1i}$$

$$\nabla \times \boldsymbol{H}_{1i} = \frac{1}{2}\boldsymbol{J}_{1i} + \epsilon\partial \boldsymbol{E}_{2i}$$

$$\nabla \times \boldsymbol{H}_{2i} = \frac{1}{2}\boldsymbol{J}_{2i} + \epsilon\partial \boldsymbol{E}_{1i}$$

Assume we make the following exchange,

(69)

$$\boldsymbol{H}_{2i} \rightarrow \boldsymbol{H}_{1i}$$

$$\boldsymbol{H}_{1i} \rightarrow \boldsymbol{H}_{2i}$$

We obtains,

(70)

$$\nabla \times \boldsymbol{E}_{1i} = -\mu\partial \boldsymbol{H}_{1i}$$

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

$$\nabla \times \boldsymbol{H}_{2i} = \frac{1}{2}\boldsymbol{J}_{1i} + \epsilon\partial \boldsymbol{E}_{2i}$$

$$\nabla \times \boldsymbol{H}_{1i} = \frac{1}{2}\boldsymbol{J}_{2i} + \epsilon\partial \boldsymbol{E}_{1i}$$

Or

(71)

$$\nabla\times\boldsymbol{E}_{1i}=-\mu\partial\boldsymbol{H}_{1i}$$

$$\nabla\times\boldsymbol{H}_{1i}=\frac{1}{2}\boldsymbol{J}_{2i}+\epsilon\partial\boldsymbol{E}_{1i}$$

(72)

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

$$\nabla\times\boldsymbol{H}_{2i}=\frac{1}{2}\boldsymbol{J}_{1i}+\epsilon\partial\boldsymbol{E}_{2i}$$

The above equation, shows that $\boldsymbol{E}_{1i}$ $\boldsymbol{H}_{1i}$ is actually produced by current $\boldsymbol{J}_{2i}$. Considering that we have made exchange Eq.(69), now we need to make a inverse exchange with Eq(69). Afterward we know that actually $\boldsymbol{E}_{1i}$ $\boldsymbol{H}_{2i}$ is produced by $\boldsymbol{J}_{2i}$.

Similarly we have that, $\boldsymbol{E}_{2i}$ $\boldsymbol{H}_{1i}$ is produced by $\boldsymbol{J}_{1i}$. This solution is not we like.

We need a solution that $\boldsymbol{E}_{1i}$ $\boldsymbol{H}_{1i}$ as retarded wave and $\boldsymbol{E}_{2i}$ $\boldsymbol{H}_{2i}$ as advanced wave. We have proved in this situation the mutual energy current flow to the outside of the infinite big sphere be come vanished. That will further guarantee that the mutual energy current flow from emitter to the absorber is equation in any surface between the emitter and the absorber. The solution of equations Eq.(71,72) can not offer us this condition. If $\boldsymbol{E}_{1i}$ $\boldsymbol{H}_{2i}$ is produced from $J_{2i}$, $\boldsymbol{E}_{1i}\times\boldsymbol{H}_{2i}$ can not vanish at infinite big sphere. Similar to $\boldsymbol{E}_{2i}\times\boldsymbol{H}_{1i}$. Hence the mutual energy current can not vanish at the at the infinite big sphere, i.e. Eq.(6) do not satisfy. This make our theory fail.

We got a wrong solution. This road cannot go through. We have spent a lot of time, but the result is not what we would like. Hence we have to go back and check other situations which perhaps are better. In next version of this article we will correct this problem.

# 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 and the advanced wave together produced the mutual energy current. In microcosm the energy is only transferred by mutual energy current. The self-energy current in microcosm doesn't existent. The pointing theorem is not satisfied for the absorber or emitter in the photon model. 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 a modified equation from Maxwell equations. In this equation all self-energy items are all vanishes. 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 interpreted as line polarization / circle polarization and hence interprets the concept of spin of the photon. The above photon model is derived from electromagnetic field with Maxwell theory, but it very likely also suit the wave of other particles, for example electrons.

We have try to apply the self-energy items vanishes in microcosm to build the photon model. This way has some problem, because we can not prove the mutual energy current vanishes in the infinite big sphere. The requirement the mutual energy current vanishes in the infinite big sphere is the key point of our theory, if this fail the whole theory is fail. The authors have the idea how to solve this problem. In next version of this article the authors will correct the problem. Even this road is fail, the authors still keep it at this version, hope this will help the reader to understand the thought development.

[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