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

Shuang-ren Zhao*, Kevin Yang, Kang Yang, Xingang Yang and Xintie Yang†

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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 explained using this photon model. The total energy transfer can be divided as self-energy transfer and the mutual energy transfer. It is possible the self-energy current transfer half the total energy and it also possible that the part of self-energy part has no contribution to the energy transferring of the photon. In the latter, the self-energy items is canceled by the advanced wave of the emitter current and the retarded wave of the absorber current or canceled by the collapse back waves. The this collapsed wave is still satisfy Maxwell equation or some time-reversed Maxwell equation. Furthermore, the author found the photon should satisfy the Maxwell equations in microcosm. Energy can be 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 traditional concept of wave function collapse in quantum mechanics is not needed in the authors' photon model. The authors believe the concept of the traditional wave collapse is coursed by the misunderstanding about the energy current. Traditionally we have only the

*Shuang-ren Zhao is with imrecons, in London, Canada, president@imrecons.com.

†Xintie Yang is with Aviation Academy, Northwestern Polytechnical University, Xi'an, China

energy current based on Poynting vector which is always diverges from the source. Hence there is the requirement for the energy to collapse to its absorber. After we know that the electromagnetic energy is actually transferred by mutual energy current which is a wave diverging in the beginning and converging in the end, then we do not need the wave function to collapse. The concept energy is transferred by the mutual energy current can be extended from photon to any other particles for example electron. Electron should have similarly mutual energy current to carry their energy from one place to another and do not need the wave function to collapse.

1 Introduction

The Maxwell equations have two solutions one is retarded wave, another is advanced wave. Traditional electromagnetic theory thinks there exists 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, 8]. J. Cramer built the transactional interpretation for quantum mechanics by applied the absorber theory [4, 5] in around 1980. In 1978 Wheeler introduced the delayed choice experiment, which strongly implies the existence of the advanced wave [7, 17]. The delayed choice experiment is further developed to the delayed choice quantum eraser experiment[6], and quantum entanglement ghost image and the ghost image clearly offers the advanced wave picture[3]. The first author of this article has introduced the mutual energy theory in 1987 [9, 19, 18]. Later he noticed that in the mutual energy theorem, the receive antenna sends advanced wave [10] and begins to apply it to the study of the photon and the other quantum particles[14, 15, 13]. 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 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 radiation which should satisfy Maxwell equations. Hence Maxwell equations are a macrocosm field. In microcosm, only singular photon we are not clear whether the Maxwell equations still works. Hence the for 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.

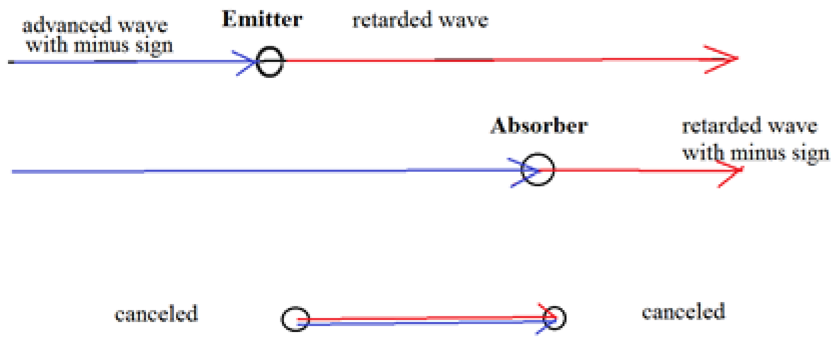

Figure 1: The Wheeler and Feynman model. The emitter sends retarded wave to right shown as red arrow. The emitter sends advanced wave to the left which is blue. We have drawn the arrow in the opposite direction to the advanced wave. This is same to the absorber. However, the retarded wave of the absorber 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..

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 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 x. The advanced wave is sent to the negative direction along x. We take color red to draw the retarded waves. We take color blue to draw the advanced wave, see the Figure 2. 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.

All this model looks very good and it is very success in cosmography, but it is difficult to be believe. First 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. 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? 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. Cramer 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[9, 19, 18, 14, 15, 13] will play an important role.

3 The photon model of the authors

The authors believe that in the traditional electromagnetic field theory there are big mistakes to the understanding the Poynting theorem and Lorentz reciprocity theorem. First the energy current calculated by Poynting vector actually do not carry any energy in microcosm world like photons. Second the Lorentz reciprocity theorem actually is not a physic theorem but only mathematical transform of the mutual energy theorem which is a real physic theorem.

The authors believe that the energy transfer for a singular photon from emitter to the absorber can only be described with the mutual energy theorem. In microcosm, the self-energy have no any contribution to the energy transfer of a singular photon. Poynting theorem offers the theory about the self-energy hence Poynting theorem is not important in microcosm. In this article we will show that the macrocosm Poynting theorem can be derived from the mutual energy theorem which describes the energy transfer of a singular photon. We have known that in Fourier domain the mutual energy theorem and the Lorentz theorem can be derived from each others. Hence there is question both mutual energy theorem and Lorentz theorem which is the original physic theorem, which one is just a mathematical transform of a real physic theorem? The author believe the the mutual energy theorem is the original physic theorem. The Lorentz theorem is only a mathematical transform of the mutual energy theorem. In antenna calculation we never need the concept of wave function collapse. We use Lorentz theorem to calculate the antenna problem which actually is because the Lorentz theorem contains the results of mutual energy theorem. Since photon as a system with emitter and absorber can be seen as a system with transmit antenna and a receive antenna, it is possible to us to apply the mutual energy theorem to the the photon system.

The first author of this article has introduced the mutual energy theorem in 1987[9], found that the mutual energy current is just a inner product of two electric fields and pointed out that mutual energy theorem is not just a transform of reciprocity theorem it is established in lossless media, but the reciprocity theorem is established in symmetric media. The first author of this article has applied the mutual energy theorem to spherical waves and plane waves [9, 19, 18]. The authors have proven that the mutual energy theorem can be derived from Poynting theorem and hence it is a energy theorem[10] and hence the concept self-energy, mutual energy, mutual energy current are all suitable. In that article also proved that the reciprocity can be derived from the mutual energy theorem. The author also proved that in the lossy media, the mutual energy theorem is suitable but the the Lorentz theorem isn't[11]. Afterwords the author begin to apply the mutual energy theorem to the photon model and quantum physics[12, 16, 15, 14]. However the discussions are restrict to the field in Fourier domain and the discussion only restrict to the mutual energy current but not self-energy current. In photon model the self-energy current is also very important. Is self-energy current transfer energy? If it doesn't transfer energy, is it collapsed or canceled by some other thing or it just send to the infinite? In this article the authors will continue to prove that photon is nothing else but just the mutual energy current. The authors will show that the mutual energy current is never collapse and it is can be seen as plane wave in a wave guide which has sharped tip at the two ends and which is very thick in the middle. The authors will prove this photon model theory based on the classical electromagnetic theorem with Maxwell equations. The authors will show that the Poynting theorem (and hence the self-energy current) in macrocosm is only a combination of many small mutual energy currents in microcosm.

Next section we need to revise the Poynting theorem.

4 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.

$$\oiint_{\Gamma} (\overrightarrow{E} \times \overrightarrow{H}) \cdot \hat{n} d\Gamma = \iiint_{V} (\overrightarrow{J} \cdot \overrightarrow{E} + \partial u) \, dV \tag{1}$$

where $\overrightarrow{E}$ is the electric field; $\overrightarrow{H}$ is the magnetic H-field; $\overrightarrow{J}$ is the current intensity; Γ is the boundary surface of volume V; u is energy saved on the volume

V; $\hat{n}$ is unit norm vector of the surface Γ; u is the electromagnetic field energy intensity. ∂u is defined as

$$\partial u \equiv \frac{\partial u}{\partial t} = \overrightarrow{E} \cdot \frac{\partial \overrightarrow{D}}{\partial t} + \overrightarrow{H} \cdot \frac{\partial \overrightarrow{B}}{\partial t} \tag{2}$$

where $\overrightarrow{D} = \epsilon \overrightarrow{E}$ is the electric displacement; $\overrightarrow{B} = \mu B$ is magnetic B-field; ϵ,μ are permittivity and permeability; ∂u is the increase of the energy intensity. The above equation is Poynting theorem, which tell us the energy current come through the surface to the inside the region $\oiint_\Gamma (\overrightarrow{E} \times \overrightarrow{H}) \boldsymbol{.} \hat{n} d\Gamma$ is equal to the energy loss $\iiint_V (\overrightarrow{J} \boldsymbol{.} \overrightarrow{E}) dV$ in the volume V and increase of the energy inside the volume $\iiint (\partial u) dV$. In this article energy current is equivalent to energy flux. Energy current sounds more real and energy flux sounds more virtual, the author think the energy is real and hence the energy current is chosen instead of energy flux in this article. But actually energy current is just energy flux.

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 it 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 will 99.99% also satisfies Maxwell equations. This point of view will be applied in the following sections.

5 3D photon model in the time-domain with mutual energy current

Assume the i-th photon is sent by an emitter and received by an absorber. The current in the emitter can be written as $\overrightarrow{J}_{1i}$, the current in the absorber can be written as $\overrightarrow{J}_{2i}$. 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 $\overrightarrow{J}_{1i}$ is associated only to a retarded wave and the absorber $\overrightarrow{J}_{2i}$ 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 1. It should be notice that in the following article there two kinds of filed, one it the photon's field which will have subscript i, and this is microcosm field for example $\overrightarrow{J}_{1i}$, $\overrightarrow{E}_{1i}$, $\overrightarrow{H}_{1i}$. Another is the field without the subscript i which is the macrocosm field, for example $\overrightarrow{J}_1$, $\overrightarrow{E}_1$.

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 $\overrightarrow{J}_{1i}$ produces retarded wave $\xi_{1i} = [\overrightarrow{E}_{1i}, \overrightarrow{H}_{1i}]$. $\overrightarrow{J}_{2i}$ produces advanced wave $\xi_{2i} = [\overrightarrow{E}_{2i}, \overrightarrow{H}_{2i}]$.

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. $\xi_{1i} = [\overrightarrow{E}_{1i}, \overrightarrow{H}_{1i}]$ which is produced by $\overrightarrow{J}_{1i}$ and ξ_{2i}=$[\overrightarrow{E}_{2i}, \overrightarrow{H}_{2i}]$ which is produced by $\overrightarrow{J}_{2i}$. Substitute $\xi_i = \xi_{1i} + \xi_{2i}$ and $\overrightarrow{J}_i = \overrightarrow{J}_{1i} + \overrightarrow{J}_{2i}$ to Eq.(1). From Eq.(1) subtract the following self-energy items in the following,

$$-\oiint_{\Gamma} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma = \iiint_{V} (\overrightarrow{J}_{1i} \cdot \overrightarrow{E}_{1i} + \partial u_{1i})\, dV \tag{3}$$

$$-\oiint_{\Gamma} (\overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma = \iiint_{V} (\overrightarrow{J}_{1i} \cdot \overrightarrow{E}_{1i} + \partial u_{1i})\, dV \tag{4}$$

which becomes

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

$$+ \iiint_{V} (\overrightarrow{E}_{1i} \cdot \partial \overrightarrow{D}_{2i} + \overrightarrow{E}_{2i} \cdot \partial \overrightarrow{D}_{1i} + \overrightarrow{H}_{2i} \partial \overrightarrow{B}_{1i} + \overrightarrow{H}_{2i} \overrightarrow{B}_{1i})\, dV \tag{5}$$

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.

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 $\xi_{1i} = [\overrightarrow{E}_{1i}, \overrightarrow{H}_{1i}]$ is retarded wave, $\xi_{2i} = [\overrightarrow{E}_{2i}, \overrightarrow{H}_{2i}]$ is advanced wave. On the big sphere surface Γ, ξ_{1i} is no zero at a future time T_Γ to $T_\Gamma + \Delta t$. $T_\Gamma = \frac{R_\Gamma}{c}$, 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 $\overrightarrow{J}_{1i} \neq 0$). Assume the distance between the emitter and

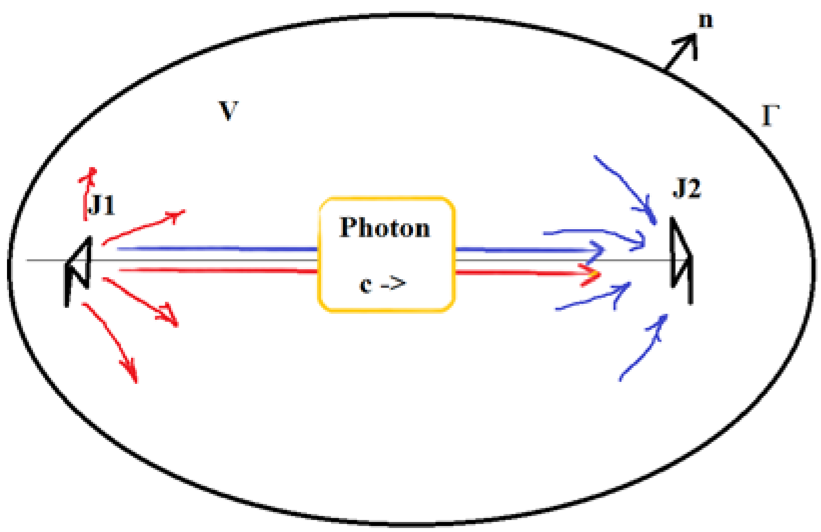

Figure 2: Photon model. There is an emitter and an absorber, emitter send retarded wave. The absorber sends advanced wave. The photon is sent out in $t = 0$, in short time Δt, hence photon is sent out from $t = 0$ to Δt, the photon has speed c. After a time T it travels to distance $d = cT$, where has 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.

the absorber is d with $d \ll R_\Gamma$. $J_{2i} \neq 0$, Is at time T to $T+\Delta t$, $T \ll T_\Gamma$. ξ_{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 (ξ_{1i} and ξ_{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 $T \rightarrow 0$. Hence we have,

$$-\oiint_{\Gamma}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}+\overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma=0 \tag{6}$$

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 ξ_1 and ξ_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

$$-\iiint_V(\overrightarrow{J}_{1i}\cdot\overrightarrow{E}_{2i})\,dV=\iiint_V(\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_{1i})\,dV$$
$$+\iiint_V(\overrightarrow{E}_{1i}\cdot\partial\overrightarrow{D}_{2i}+\overrightarrow{E}_{2i}\cdot\partial\overrightarrow{D}_{1i}+\overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i}+\overrightarrow{H}_{2i}\partial\overrightarrow{B}_{11})\,dV \tag{7}$$

The left side of Eq.(7) is the sucked energy by advanced wave $\overrightarrow{E}_{2i}$ from $\overrightarrow{J}_{1i}$, which is the emitted energy of the emitter. $\iiint_V(\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_{1i})\,dV$ is the retarded wave E_{1i} act on the current $\overrightarrow{J}_{2i}$. It is the received energy of J_{2i}. $\iiint_V(\overrightarrow{E}_{1i}\cdot\partial\overrightarrow{D}_{2i}+\overrightarrow{E}_{2i}\cdot\partial\overrightarrow{D}_{1i}+\overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i}+\overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i})dV$ 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, $\iiint_V(\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_{1i})\,dV$ is the loss power of absorber $\overrightarrow{J}_{2i}$. $-\iiint_V(\overrightarrow{J}_{1i}\cdot\overrightarrow{E}_{2i})\,dV$ is the energy supply of $\overrightarrow{J}_{1i}$.

Assume V_1 is a volume contains only the emitter $\overrightarrow{J}_{1i}$. 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.,

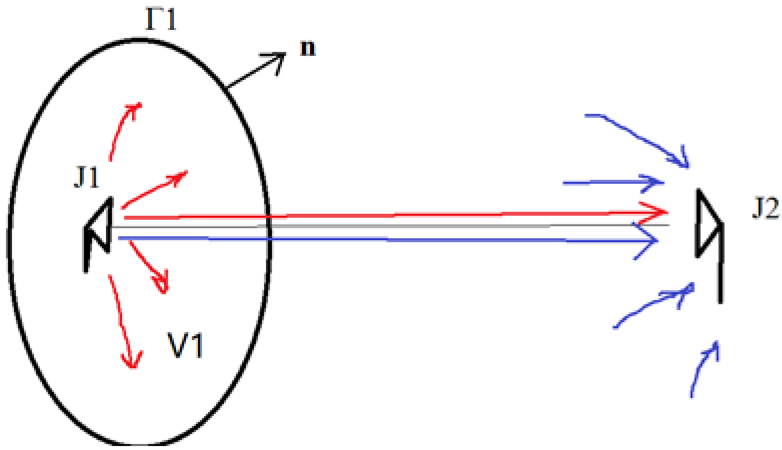

Figure 3: Red arrow is retarded wave, blue line is advanced wave. The arrow direction shows the direction of the energy current. The emitter contains inside the volume V_1. Γ_1 is the boundary surface of V_1. The energy current consist of the retarded wave and the advanced wave..

$$\oiint_{\Gamma_1} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n}\, d\Gamma \neq 0 \tag{8}$$

See Figure 3.

Eq.(5) can be rewritten as,

$$-\iiint_{V_1} (\overrightarrow{J}_{1i} \cdot \overrightarrow{E}_{2i})\, dV = \oiint_{\Gamma_1} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma$$

$$+ \iiint_{V_1} (\overrightarrow{E}_{1i} \cdot \partial \overrightarrow{D}_{2i} + \overrightarrow{E}_{2i} \cdot \partial \overrightarrow{D}_{1i} + \overrightarrow{H}_{2i} \partial \overrightarrow{B}_{1i} + \overrightarrow{H}_{2i} \partial \overrightarrow{B}_{1i})\, dV \tag{9}$$

In this formula, $-\iiint_{V_1} (\overrightarrow{J}_{1i} \cdot \overrightarrow{E}_{2i})\, dV$ is the emitted energy. $\oiint_{\Gamma_1} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma$ is the energy current from the emitter to the absorber. $\iiint_{V_1} (\overrightarrow{E}_{1i} \cdot \partial \overrightarrow{D}_{2i} + \overrightarrow{E}_{2i} \cdot \partial \overrightarrow{D}_{1i} + \overrightarrow{H}_{2i} \partial \overrightarrow{B}_{1i} + \overrightarrow{H}_{2i} \partial \overrightarrow{B}_{1i})\, dV$ is the increase of the energy inside volume V_1. Figure 3 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 3, we always draw the arrow in the energy current directions. For advance wave the energy current is on the opposite direction of the wave.

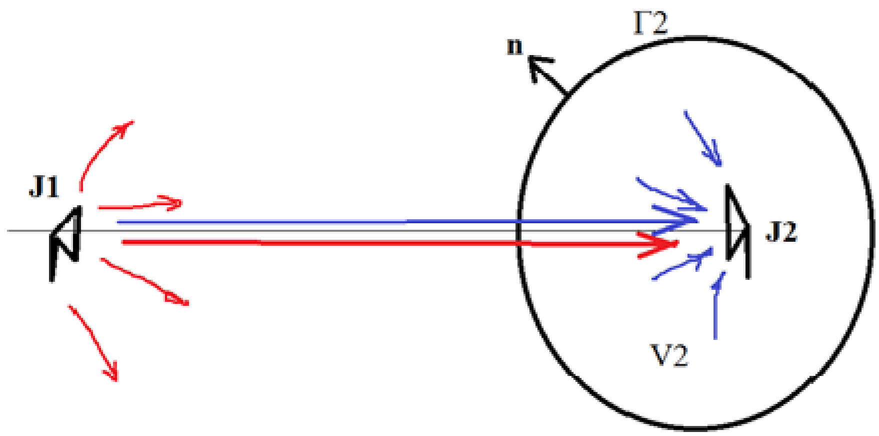

Figure 4: Choose the volume V_2 is close to the absorber. Red arrows are retarded wave, blue arrows are advanced wave. The direction of retarded wave is same as the direction of red arrow. The direction of advanced wave is at the opposite direction of the blue arrow. The arrow direction (red or blue) is always at the energy transfer direction.

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

$$\oiint_{\Gamma_2} (\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i} + \overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma$$

$$= \iiint_{V_2} (\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_1)\,dV + \iiint_{V_2} (\overrightarrow{E}_{1i}\cdot\partial\overrightarrow{D}_{2i} + \overrightarrow{E}_{2i}\cdot\partial\overrightarrow{D}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i})\,dV \tag{10}$$

From the above discussion it is clear that,

I.$\oiint_\Gamma (\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i} + \overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i})\cdot nd\Gamma$ can be seen as energy current on the surface Γ (or energy flux).

II.$\partial u_{12} = (\overrightarrow{E}_{1i}\cdot\partial\overrightarrow{D}_{2i} + \overrightarrow{E}_{2i}\cdot\partial\overrightarrow{D}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i})$ is the increase of the photon energy distribution.

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

IV. $\iiint_{V_2}(\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_{1i})\,dV$ is the absorbed energy of the absorber.

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

$$(\overrightarrow{E}_{1i}\cdot\partial\overrightarrow{D}_{2i} + \overrightarrow{E}_{2i}\cdot\partial\overrightarrow{D}_{1i} + \overrightarrow{H}_{1i}\partial\overrightarrow{B}_{2i} + \overrightarrow{H}_{2}\partial\overrightarrow{B}_{1i})$$

$$= \overrightarrow{E}_{1i}\cdot\partial\epsilon\overrightarrow{E}_{2i} + \overrightarrow{E}_{2i}\cdot\partial\epsilon\overrightarrow{E}_{1i} + \overrightarrow{H}_{2i}\partial\mu\overrightarrow{H}_{1i} + \overrightarrow{H}_{2i}\partial\mu\overrightarrow{H}_{1i}$$

$$= \partial(\epsilon \overrightarrow{E}_{1i} \cdot \overrightarrow{E}_{2i} + \mu \overrightarrow{H}_{1i} \cdot \overrightarrow{H}_{2i}) = \partial u_{12i} \tag{11}$$

Where $u_{12i} = \epsilon \overrightarrow{E}_{1i} \cdot \overrightarrow{E}_{2i} + \mu \overrightarrow{H}_{1i} \cdot \overrightarrow{H}_{2i}$. 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 $u_{12i}(t = -\infty) = u_{12i}(t = +\infty) = constant$

$$\int_{-\infty}^{\infty} dt \iiint_{V_i} \partial u_{12i} dV = \iiint_{V_i} (u_{12i}(t = +\infty) - u_{12i}(t = -\infty)) = 0 \tag{12}$$

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,

$$-\int_{-\infty}^{\infty} dt \iiint_{V} (\overrightarrow{J}_{1i} \cdot \overrightarrow{E}_{2i})\, dV = \int_{-\infty}^{\infty} dt \iiint_{V} (\overrightarrow{J}_{2i} \cdot \overrightarrow{E}_{1i}) dV \tag{13}$$

This means all energy emitter from the current J_{1i} which is the left of the above formula is received by absorber J_{2i} which is the right of the above formula. Considering Eq.(9,10 and 12,13) we have

$$\int_{-\infty}^{\infty} dt \oiint_{\Gamma_1} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma$$

$$= \int_{-\infty}^{\infty} dt \oiint_{\Gamma_1} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot (-\hat{n}) d\Gamma \tag{14}$$

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 $Q_{mi} = \oiint_{\Gamma_m} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma$, here we change the direction of n always from the emitter to the absorber, then we can get the following, see Figure 5.

$$\int_{-\infty}^{\infty} dt Q_{mk} = \int_{-\infty}^{\infty} dt Q_{1i} \qquad m = 1, 2, 3, 4, 5 \tag{15}$$

From Figure 5 we can see that the time integral of the mutual energy current on an arbitrary surface are Γ_m 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 concentrated to a small region the moment should also concentrated to that small region. In this case the energy of this mutual energy current will behaved like a particle.

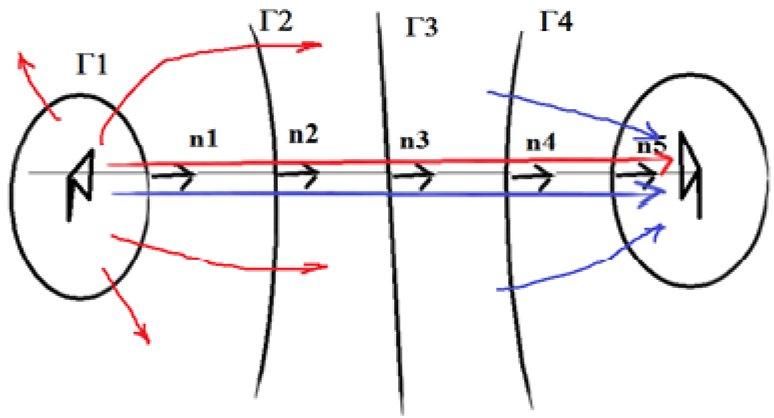

Figure 5: 5 surfaces are shown, the mutual energy current goes through each surface and integrates with time should be equal to each other.

However, it is still mutual energy current in 3D-space. Figure 5 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. The shape of the wave guide are with to sharp tips on the two ends of the wave guide and in the middle of the wave guide it become very thick. 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.

6 Self-energy items

Which equations photon should satisfy? First we think Maxwell equations. But it is seems that the Maxwell equations can only obtain the continual solution. But Photon is a particle, its all energy is sent to an absorber direction instead sent to the whole directions. How can we obtained the solution of energy transfer from emitter to the absorber from Maxwell theory? It is not easy to do. 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

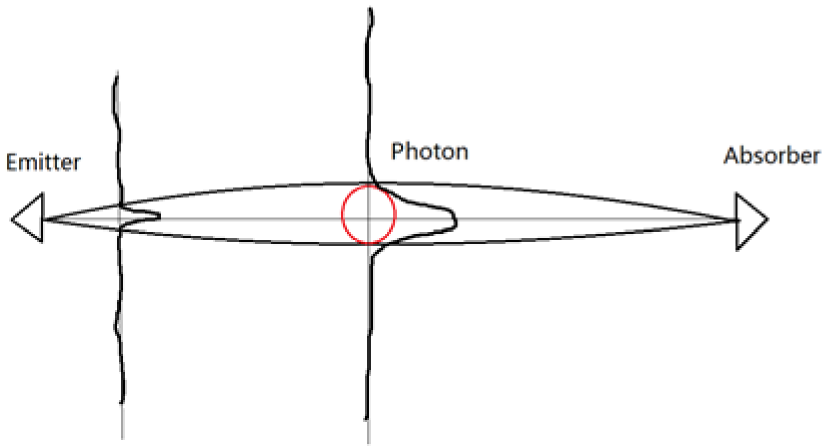

Figure 6: Photon in empty space, photon is just the mutual energy current. In some time, the photon is stayed at a place. This shows there is nothing about the concept of the wave function collapse. The mutual energy offers the wave a 1-D wave guide which ar two very sharp tips in the two ends of the wave guide. In the middle of the wave guide, it become very thick.

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 space. The problem is what will happen for the self-energy current?

6.1 Self-energy current cannot vanish

First we have to know is that the self-energy current cannot vanish. If self-energy current vanishes, that from Poynting theorem Eq.(3) we can take a volume V_{ab} which is between two sphere surface Γ_a and Γ_b. In this volume there is no current hence we have,

$$-(\oiint_{\Gamma_b}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma-\oiint_{\Gamma_a}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma)=\iiint_{V_{ab}}\partial u_{1i}\,dV \qquad (16)$$

The self-energy current $\oiint_{\Gamma_b}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma=0$ means the right side of the above formula is vanishes, that also means the left side of the above formula should vanish too. Hence we have

$$\iiint\limits_{V_{ab}} \partial u_{1i}\, dV = 0 \tag{17}$$

Where V_{ab} is the volume between the two surface Γ_a and Γ_b, or

$$\partial u_{1i} \equiv \frac{\partial u_{1i}}{\partial t} = \overrightarrow{E}_{1i} \cdot \frac{\partial \overrightarrow{D}_{1i}}{\partial t} + \overrightarrow{H}_{1i} \cdot \frac{\partial \overrightarrow{B}_{1i}}{\partial t} = 0 \tag{18}$$

or

$$\overrightarrow{E}_{1i} \cdot \epsilon \frac{\partial \overrightarrow{E}_{1i}}{\partial t} = 0 \tag{19}$$

$$\overrightarrow{H}_{1i} \cdot \mu \frac{\partial \overrightarrow{H}_{1i}}{\partial t} = 0 \tag{20}$$

In the space the wave is nearly run in the direction as a line. In this situation $\overrightarrow{E}_{1i}(t) \sim \exp(-j\omega t)$, $\frac{\partial \overrightarrow{E}_{1i}}{\partial t} = -j\omega \overrightarrow{E}_{1i}(t)$. It is same to $\overrightarrow{H}_{1i}$. Hence that the above equation ask

$$\overrightarrow{E}_{1i} \cdot \overrightarrow{E}_{1i} = 0 \tag{21}$$

$$\overrightarrow{H}_{1i} \cdot \overrightarrow{H}_{1i} = 0 \tag{22}$$

That means the fields $\overrightarrow{E}_{1i}$, $\overrightarrow{H}_{1i}$ must all vanish. It is same to $\overrightarrow{E}_{2i}$, $\overrightarrow{H}_{2i}$ which should also vanish. If all the fields vanish, the mutual energy current also vanishes, there is no any energy can send from emitter to the absorber. We know that there is energy send from emitter to the absorber and hence the self-energy current $\oiint_\Gamma (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma$ and $\oiint_\Gamma (\overrightarrow{E}_{2i} \times \overrightarrow{H}_{2i}) \cdot \hat{n} d\Gamma$ can not vanish. We can think the effect of self-energy is to help the mutual energy current to transfer the energy from emitter to absorber. After mutual energy current has finish the work, the energy of photon has sent from emitter to the absorber. The self-energy stayed in the space. What this self-energy should do? If it doesn't return the emitter and absorber, this energy will continue loss to the outside of our universe. Our universe will continually loss energy that is also very strange. Hence we must think the possibility this energy can return to the emitter and absorber.

For self-energy current we can assume,

(a) The self-energy items are existent, they 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 from self-energy current, but the advanced wave gains the same amount of energy from self-energy current. The part of self-energy sent by the emitter can be seen as it is transferred to the infinity. The self-energy sent by the absorber can

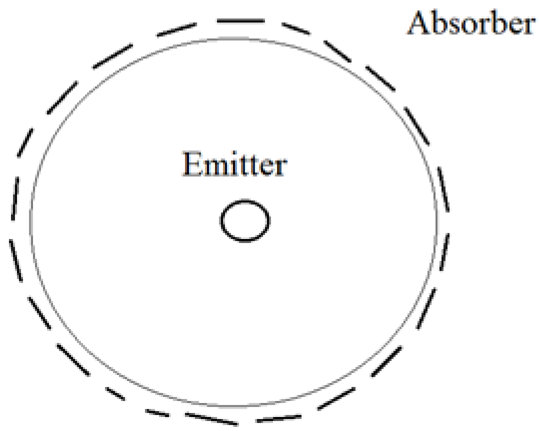

Figure 7: This shows emitters all at the center of the sphere. The absorbers are distributed at the surface of the sphere. The absorbers are the environment. We assume the absorbers are surrounded the emitters. This is our simplified macrocosm model.

be seen as some energy received from the infinity. In this case the self-energy has contribution to the energy transfer.

(b) Because self-energy current 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 also the advanced wave and also retarded wave self-energy current. The absorber doesn't loss or increase energy through the self-energy current items. Hence, the self-energy items have no contribution to the energy transfer.

(c) The self-energy current is existent. The help the mutual energy to send from emitter to the absorber and hence the self-energy has come the the whole space. Afterwards, the self-energy collapse back to the emitter and absorber. Hence the self-energy current do not have any contribution to the energy transfer from emitter to the absorber.

The Figure 7 offers our simplified macrocosm model. In this model the emitter is stay at the center of the sphere. In a big sphere there is many absorbers. This macrocosm model can be easily extended to more general situation where the Emitter is not only stay at the center of the sphere but at a region close to the center. The absorber is not only on the sphere but at all the place outside the sphere.

6.2 The idea of (a)

We first consider the idea of (a). The self-energy current which is retarded wave sent by the emitter is go to the infinity. The self-energy current sent by the absorber is also go to the infinity. This way the absorber obtained the energy which is equal to the lost energy of the emitter. Hence self-energy join the energy transfer. The energy transferred not only by the mutual energy current but also the self-energy current. We will prove in this situation the self-energy current and the mutual energy current each has half contribution to the total energy transferring.

If there is wave guide between the emitter to the absorber, the self-energy current is possible to transfer from the emitter to the absorber.

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 to be sent to infinity or sent to absorber? 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 (a) there is still some problem.

However, in the following we will still continue working at the idea (a) and we will prove that the Poynting theorem is satisfied in macrocosm for this situation.

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.

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 7. Assume self-energy doesn't vanish corresponding to the idea (a) We actually endorse the idea (c), but first we check the idea (a), 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 (a) Maxwell equations are still satisfy for the macrocosm. Assume for the i-th photon the items of self-energy doesn't vanish, i.e.,

$$-\oiint_{\Gamma}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i})\cdot nd\Gamma=\iiint_{V}(\overrightarrow{J}_{1i}\cdot\overrightarrow{E}_{1i}+\partial u_{1i})\,dV \tag{23}$$

$$-\oiint_{\Gamma}(\overrightarrow{E}_{2i}\times\overrightarrow{H}_{2i})\cdot nd\Gamma=\iiint_{V}(\overrightarrow{J}_{2i}\cdot\overrightarrow{E}_{2i}+\partial u_{2i})\,dV \tag{24}$$

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

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

$$= \iiint_V (\overrightarrow{J}_{1i}.\overrightarrow{E}_{2i} + \overrightarrow{J}_{2i}.\overrightarrow{E}_{1i})\, dV$$

$$+ \iiint_V (\overrightarrow{E}_{1i} \cdot \partial\overrightarrow{D}_{2i} + \overrightarrow{E}_{2i} \cdot \partial\overrightarrow{D}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i} + \overrightarrow{H}_{2i}\partial\overrightarrow{B}_{1i})\, dV \tag{25}$$

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

$$- \oiint_\Gamma (\overrightarrow{E}_{1i} + \overrightarrow{E}_{2i})\times(\overrightarrow{H}_{1i} + \overrightarrow{\mathrm{H}}_{2i}).\hat{n}d\Gamma$$

$$= \iiint_V (\overrightarrow{J}_{1i} + \overrightarrow{J}_{2i}).(\overrightarrow{E}_{2i} + \overrightarrow{E}_{1i})\, dV$$

$$+ \iiint_V (\overrightarrow{E}_{1i} + \overrightarrow{E}_{2i}) \cdot \partial(\overrightarrow{D}_{1i} + \overrightarrow{D}_{2i}) + (\overrightarrow{H}_{1i} + \overrightarrow{H}_{2i})\partial(\overrightarrow{B}_{1i} + \overrightarrow{B}_{2i})\, dV \tag{26}$$

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

$$-\sum_i \oiint_\Gamma (\overrightarrow{E}_{1i} + \overrightarrow{E}_{2i}) \times (\overrightarrow{H}_{1i} + \overrightarrow{H}_{2i}) \cdot \hat{n}d\Gamma$$

$$= \sum_i \iiint_V (\overrightarrow{J}_{1i} + \overrightarrow{J}_{2i}).(\overrightarrow{E}_{2i} + \overleftrightarrow{E}_{1i})dV$$

$$+\sum_i \iiint_V (\overrightarrow{E}_{1i} + \overrightarrow{E}_{2i}) \cdot \partial(\overrightarrow{D}_{1i} + \overrightarrow{D}_{2i}) + (\overrightarrow{H}_{1i} + \overrightarrow{H}_{2i})\partial(\overrightarrow{B}_{1i} + \overrightarrow{B}_{2i})dV \tag{27}$$

In another side, assume
$\overrightarrow{J}_1 = \sum_i \overrightarrow{J}_{1i}$, $\overrightarrow{J}_2 = \sum_i \overrightarrow{J}_{2i}$, $\overrightarrow{E}_1 = \sum_i \overrightarrow{E}_{1i}$, $\overrightarrow{E}_2 = \sum_i \overrightarrow{E}_{2i}$, and so on. Hence there is,

$$(\overrightarrow{E}_1 + \overrightarrow{E}_2)\times(\overrightarrow{H}_1 + \overrightarrow{H}_2)$$

$$= (\sum_i \overrightarrow{E}_{1i} + \sum\nolimits_j \overrightarrow{E}_{2j})\times(\sum\nolimits_m \overrightarrow{H}_{1m} + \sum\nolimits_n \overrightarrow{H}_{2n})$$

$$= \sum_i \overrightarrow{E}_{1i}\times\sum_m \overrightarrow{H}_{1m} + \sum_i \overrightarrow{E}_1 i\times\sum_n \overrightarrow{H}_{2n} + \sum_j \overrightarrow{E}_{2j}\times\sum_m \overrightarrow{H}_{1m} + \sum_j \overrightarrow{E}_{2j}\times\sum_n \overrightarrow{H}_{2n} \tag{28}$$

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

$$\sum_i \overrightarrow{E}_{1i} \times \sum_m \overrightarrow{H}_{1m} = \sum_{im} \overrightarrow{E}_{1i} \times \overrightarrow{H}_{1m} = \sum_i \overrightarrow{E}_{1i} \times H_{1i} \tag{29}$$

In the above, considering $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1m}=0$, 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

$$\begin{aligned}&(\overrightarrow{E}_1+\overrightarrow{E}_2)\times(\overrightarrow{H}_1+\overrightarrow{H}_2)\\=&\sum_i(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i}+\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}+\overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i}+\overrightarrow{E}_{2i}\times\overrightarrow{H}_{2i})\\=&\sum_i(\overrightarrow{E}_{1i}+\overrightarrow{E}_{2i})\times(\overrightarrow{H}_{1i}+\overrightarrow{H}_{2i})\end{aligned}\tag{30}$$

And similarly we have,

$$(\overrightarrow{J}_1+\overrightarrow{J}_2)\times(\overrightarrow{E}_1+\overrightarrow{E}_2)=\sum_i(\overrightarrow{J}_{1i}+\overrightarrow{J}_{2i})\times(\overrightarrow{E}_{1i}+\overrightarrow{E}_{2i})\tag{31}$$

$$(E_1+E_2)\cdot\partial(D_1+D_2)=\sum_i(E_{1i}+E_{2i})\cdot\partial(D_{1i}+D_{2i})\tag{32}$$

$$(\overrightarrow{H}_1+\overrightarrow{H}_2)\cdot\partial(\overrightarrow{B}_1+\overrightarrow{B}_2)=\sum_i(\overrightarrow{H}_{1i}+\overrightarrow{H}_{2i})\cdot\partial(\overrightarrow{B}_{1i}+\overrightarrow{B}_{2i})\tag{33}$$

Considering Eq.(30), Eq.(27) can be written as,

$$\begin{aligned}&-\oint\!\!\!\oint_\Gamma(\overrightarrow{E}_1+\overrightarrow{E}_2)\times(\overrightarrow{H}_1+\overrightarrow{H}_2)\cdot\hat{n}d\Gamma\\&=\iiint_V(\overrightarrow{J}_1+\overrightarrow{J}_2)\cdot(\overrightarrow{E}_2+\overrightarrow{E}_1)dV\\&+\iiint_V(\overrightarrow{E}_1+\overrightarrow{E}_2)\cdot\partial(\overrightarrow{D}_1+\overrightarrow{D}_2)+(\overrightarrow{H}_1+\overrightarrow{H}_2)\partial(\overrightarrow{B}_1+\overrightarrow{B}_2)\,dV\end{aligned}\tag{34}$$

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

$$\begin{aligned}&-\oint\!\!\!\oint_\Gamma(\overrightarrow{E}_1+\overrightarrow{E}_2)\times(\overrightarrow{H}_1+\overrightarrow{H}_2)\cdot\hat{n}d\Gamma\\&=\iiint_{V_1}\overrightarrow{J}_1\cdot(\overrightarrow{E}_2+\overrightarrow{E}_1)dV\\&+\iiint_{V_1}(\overrightarrow{E}_1+\overrightarrow{E}_2)\cdot\partial(\overrightarrow{D}_1+\overrightarrow{D}_2)+(\overrightarrow{H}_1+\overrightarrow{H}_2)\partial(\overrightarrow{B}_1+\overrightarrow{B}_2)\,dV\end{aligned}\tag{35}$$

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 $\overrightarrow{J}_1$ or produced by the advanced wave of the absorber in the environment. We can think all the field is produced by the source current $\overrightarrow{J}_1$, hence we have $\overrightarrow{E} = \overrightarrow{E}_1 + \overrightarrow{E}_2$, $\overrightarrow{D} = \overrightarrow{D}_1 + \overrightarrow{D}_2$, $\overrightarrow{H} = \overrightarrow{H}_1 + \overrightarrow{H}_2$, $\overrightarrow{B} = \overrightarrow{B}_1 + \overrightarrow{B}_2$. Here the field $\overrightarrow{E}$,$\overrightarrow{H}$ are total electromagnetic field in macrocosm, which are thought produced by emitter J_1, hence we have

$$-\oint\!\!\!\oint_{\Gamma_1}(\overrightarrow{E}\times\overrightarrow{H}).\hat{n}d\Gamma$$

$$=\iiint_V \overrightarrow{J}_1 \cdot \overrightarrow{E}\, dV + \iiint_{V_1}(\overrightarrow{E} \cdot \partial\overrightarrow{D} + \overrightarrow{H}.\partial\overrightarrow{B})\, dV \tag{36}$$

This is the Poynting theorem in macrocosm. In this formula there is only emitter current $\overrightarrow{J}_1$. The field $\overrightarrow{E}$,$\overrightarrow{H}$ can be seen as retarded wave but it is actually consist of both retarded wave and advanced wave in microcosm.

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, w also assume there is the mutual energy current between the emitter and the absorber. All this means that for a singular photon it satisfies the Maxwell equations. 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 solutions 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 on 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 space.

6.3 For the idea of (b)

In this situation all self-energy current items don't transfer energy. The energy of photon is transferred only through the mutual energy items.

We can assume the emitter also send an advanced wave which have the same energy current as the retarded self-energy current, but has opposite direction of energy transfer. Hence the total energy transfer of self-energy current for the emitter vanishes. We can assume for our universe the infinite far away in the future is connected to the infinite far away of the past. So the self-energy current sent out by emitter comes back to the emitter.

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 assume the retarded wave and the advanced wave of the emitter is sent out in the time $t = 0$. We assume the advanced wave and the retarded wave of the absorber is sent out by the time of $t = T = \frac{R}{c}$. Where R is the distance from emitter to the absorber. c is the light speed. In this case, the retarded wave of the emitter and the advanced wave of the absorber can be synchronized. Hence the mutual energy current of the retarded wave of the emitter and the advanced wave of the absorber can produce no zero mutual energy current.

By the way, the retarded wave of the absorber begins at time $t = T$. When this wave reached to the emitter, it is time $t = 2T$. If the emitter sends the advanced wave also at $t = 2T$, these two waves can be synchronized. However, in the above when we speak about the emitter send retarded wave and also advanced wave, both waves are started are at time 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 the emitter and the advanced wave of the absorber. There is no any mutual energy current of the retarded wave of the absorber and the advanced wave of the emitter. Hence we have,

$$-\oiint_{\Gamma}(\overrightarrow{E}_{1i}^{a}\times\overrightarrow{H}_{2i}^{r}+\overrightarrow{E}_{2i}^{r}\times\overrightarrow{H}_{1i}^{a})\cdot nd\Gamma=0$$

We will study the situation there is only the mutual energy items which contributed to the energy current. Self-energy current have no contribution to the energy transferring. The mutual energy current is also only the retarded wave of the emitter and the advanced wave of the absorber can contribute to the energy transferring.

Assume one of the current of emitters is $\overrightarrow{J}_{1i}$, which is at the origin and the current of the corresponding absorber is $\overrightarrow{J}_{2i}$, which is at the sphere, see Figure 7, here $i = 0, 1, \ldots N$. $\overrightarrow{J}_{1i}$ will produce retarded wave and advanced wave, to make thins simple we assume that

$$\overrightarrow{J}_{1i}^{r}=\overrightarrow{J}_{1i}^{a}=\overrightarrow{J}_{1i} \tag{37}$$

$$\overrightarrow{J}_{2i}^{r}=\overrightarrow{J}_{2i}^{a}=\overrightarrow{J}_{2i} \tag{38}$$

where $\overrightarrow{J}_{1i}^{r}$ and $\overrightarrow{J}_{2i}^{r}$ can only produce retarded wave. $\overrightarrow{J}_{1i}^{a}$ and $\overrightarrow{J}_{2i}^{a}$ can only produce advanced wave. The subscript 1 is corresponding to emitter. The subscript 2 is corresponding to absorber. $\overrightarrow{J}_{1i}$ can be replaced by $\overrightarrow{J}_{1i}^{r}$ and $\overrightarrow{J}_{1i}^{a}$. $\overrightarrow{J}_{2i}$ can be replaced by $\overrightarrow{J}_{2i}^{r}$ and $\overrightarrow{J}_{2i}^{a}$. According to the above discussion that the mutual energy current happens only between $\overrightarrow{J}_{1i}^{r}$ and $\overrightarrow{J}_{2i}^{a}$, which is,

$$-\oiint_\Gamma (\overrightarrow{E}^r_{1i}\times\overrightarrow{H}^a_{2i}+\overrightarrow{E}^a_{2i}\times\overrightarrow{H}^r_{1i})\cdot nd\Gamma$$

$$=\iiint_V (\overrightarrow{J}_{1i}\cdot\overrightarrow{E}_{2i})dV+\iiint_V (\overrightarrow{J}^a_{2i}\cdot\overrightarrow{E}_{1i})dV$$

$$+\iiint_V (\overrightarrow{E}^r_{1i}\cdot\partial\overrightarrow{D}^a_{2i}+\overrightarrow{E}^a_{2i}\cdot\partial\overrightarrow{D}^r_{1i}+\overrightarrow{H}^a_{2i}\partial\overrightarrow{B}^r_{1i}+\overrightarrow{H}^a_{2i}\partial B^r_{1i})dV \tag{39}$$

Or we can sum it to i,

$$-\oiint_\Gamma \sum_i (\overrightarrow{E}^r_{1i}\times\overrightarrow{H}^a_{2i}+\overrightarrow{E}^a_{2i}\times\overrightarrow{H}^r_{1i})\cdot nd\Gamma$$

$$=\iiint_V \sum_i (\overrightarrow{J}_{1i}\cdot\overrightarrow{E}_{2i})dV+\iiint_V \sum_i (\overrightarrow{J}^a_{2i}\cdot\overrightarrow{E}_{1i})dV$$

$$+\iiint_V \sum_i (\overrightarrow{E}^r_{1i}\cdot\partial\overrightarrow{D}^a_{2i}+\overrightarrow{E}^a_{2i}\cdot\partial\overrightarrow{D}^r_{1i}+\overrightarrow{H}^a_{2i}\partial\overrightarrow{B}^r_{1i}+\overrightarrow{H}^a_{2i}\partial B^r_{1i})dV \tag{40}$$

$\overrightarrow{J}^r_{2i}$ and $\overrightarrow{J}^a_{1i}$ do not produce any mutual energy current because this two fields are not synchronized. If $\overrightarrow{J}^r_{2i}$ and $\overrightarrow{J}^a_{1i}$ 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 $\overrightarrow{J}^r_{1i}$ can only be received by the absorber $\overrightarrow{J}^a_{2i}$, here $i=1,\ldots,N$. 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 $\overrightarrow{J}^r_1=\sum_i\overrightarrow{J}^r_{1i}$ and $\overrightarrow{J}^a_2=\sum_j\overrightarrow{J}^a_{2j}$, $\overrightarrow{E}^r_1=\sum_i\overrightarrow{E}^r_{1i}$, $\overrightarrow{E}^a_2=\sum_i\overrightarrow{E}_2 i^a$, consider this, Eq.(27) becomes

$$-\oiint_\Gamma (\overrightarrow{E}^r_1\times\overrightarrow{H}^a_2+\overrightarrow{E}^a_2\times\overrightarrow{H}^r_1)\cdot nd\Gamma$$

$$=\iiint_V (\overrightarrow{J}^r_1\cdot\overrightarrow{E}^a_2)dV+\iiint_V (\overrightarrow{J}_2\cdot\overrightarrow{E}^r_1)dV$$

$$+\iiint_V (\overrightarrow{E}^r_1\cdot\partial\overrightarrow{D}^a_2+\overrightarrow{E}^a_2\cdot\partial\overrightarrow{D}^r_1+\overrightarrow{H}^a_2\partial\overrightarrow{B}^r_1+\overrightarrow{H}^a_2\partial\overrightarrow{B}^r_1)dV \tag{41}$$

In the above formula we have considered that

$$\sum_{ij}\overrightarrow{E}^r_{1i}\times\overrightarrow{H}^a_{2j}=0 \tag{42}$$

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,

$$\sum_i \overrightarrow{E}^r_{1i} \times \sum_J \overrightarrow{H}^a_{2j} = \sum_{ij} \overrightarrow{E}^r_{1i} \times \overrightarrow{H}^a_{2j} = \sum_i \overrightarrow{E}^r_{1i} \times \overrightarrow{H}^a_{2i} \tag{43}$$

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

$$\sum_i \overrightarrow{E}^r_{1i} = \sum_i \overrightarrow{E}^a_{2i} \equiv \frac{1}{2}\overrightarrow{E} \tag{44}$$

$$\sum_i \overrightarrow{H}^r_{1i} = \sum_i \overrightarrow{H}^a_{2i} \equiv \frac{1}{2}\overrightarrow{H} \tag{45}$$

The above formula tell us that the total retarded wave field $\sum_i \overrightarrow{H}_{1i}$ is half of the macrocosm field. The total advanced waves from all photons $\sum_i \overrightarrow{E}_{2i}$ is the half of the macrocosm field. Where "≡" means "is defined as". Considering the above formula, we obtain,

$$\frac{1}{2} \oiint_{\Gamma} (\overrightarrow{E} \times \overrightarrow{H}) \cdot \hat{n} d\Gamma$$

$$= \frac{1}{2} \iiint_V (\overrightarrow{J}^r_1 \cdot \overrightarrow{E})\, dV + \frac{1}{2} \iiint_V (\overrightarrow{J}^a_2 \cdot E) dV + \frac{1}{2} \iiint_V (\overrightarrow{E} \cdot \partial \overrightarrow{D} + \overrightarrow{H} \cdot \partial \overrightarrow{B})\, dV \tag{46}$$

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

$$- \iiint_{V_1} (\overrightarrow{J}_1 \cdot \overrightarrow{E})\, dV = [\oiint_{\Gamma_1} (\overrightarrow{E} \times \overrightarrow{H}) \cdot \hat{n} d\Gamma + \iiint_{V_1} (\hat{E} \cdot \partial \hat{D} + \overrightarrow{H} \cdot \partial \overrightarrow{B}) dV] \tag{47}$$

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

$$- \oiint_{\Gamma} (\overrightarrow{E}^r_{1i} \times \overrightarrow{H}^r_{1i}) \cdot \hat{n} d\Gamma = \iiint_V (\overrightarrow{J}^r_{1i} \cdot \overrightarrow{E}^r_{1i} + \partial u^r_{1i})\, dV \tag{48}$$

Is cancels with the advanced items,

$$- \oiint_{\Gamma} (\overrightarrow{E}^a_{1i} \times \overrightarrow{H}^a_{1i}) \cdot n d\Gamma = \iiint_V (\overrightarrow{J}^a_{1i} \cdot \overrightarrow{E}^a_{1i} + \partial u^a_{1i}) dV \tag{49}$$

The advanced items of the absorber

$$-\oiint_{\Gamma}(E_{2i}^{a}\times H_{2i}^{a})\cdot nd\Gamma=\iiint_{V}(J_{2i}^{a}\cdot E_{2i}^{a}+\partial u_{2i}^{a})dV \tag{50}$$

Is cancels with a retarded item,

$$-\oiint_{\Gamma}(\overrightarrow{E}_{2i}^{r}\times\overrightarrow{H}_{2i}^{r})\cdot nd\Gamma=\iiint_{V}(\overrightarrow{J}_{2i}^{r}\cdot\overrightarrow{E}_{2i}^{r}+\partial u_{2i}^{a})dV \tag{51}$$

Here they cancel each other means the pure energy contribution to the emitter from the self-energy current is zero. The pure energy contribution to the absorber from the self-energy current is zero.

In this situation the Poynting theorem is still satisfied macrocosm. However this Poynting theorem is derived only from the mutual energy current. This means in macrocosm is possible the contribution of infinite small mutual energy current produced the the Poynting theorem. The macrocosm self-energy current $\oiint_{\Gamma_1}(\overrightarrow{E}\times\overrightarrow{H})\cdot\hat{n}d\Gamma$ is noting to do with the self-energy current $\oiint_{\Gamma_1}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma$and $\oiint_{\Gamma_2}(\overrightarrow{E}_{2i}\times\overrightarrow{H}_{2i})\cdot\hat{n}d\Gamma$. Microcosm self-energy currents have canceled each other.

6.4 The idea (c)

In the above idea (b) the retarded self-energy current and advanced self-energy current all send to the infinity. It looks like the retarded wave is sent the energy to outside of our universe and the advanced wave is bring some energy from outside of our universe. Even energy is balanced to the emitter, but some energy is lost to infinite space and some energy is obtained from the from infinite space. The lost energy is at the future. The gained energy is obtained from past. The energy is not balanced at future and past. Unless in our universe the infinite far away of future is actually connected to the infinite far away of the past. If we do not like to accept the concept that future is connected to the past, that is Buddhism concept, we have to found other possibility. That is the reason we consider idea (c). In the idea (c) we assume the energy transfer is same as above the idea (b), it is transferred by mutual energy current.

In the adea (c), we assume the retarded self-energy current send to the space, that helps the mutual energy current sends to the absorber. After the mutual energy is sent to the absorber, the retarded self-energy current collapses back to the emitter. It is same to the absorber, the the self-energy of retarded wave of the absorber collapses to the absorber.

To the emitter, it sends retarded wave. The collapsed wave can be seen as the wave produced by the current which is at infinite big sphere. This collapsed wave to the infinite big sphere is advanced wave. But this collapsed wave to the emitter it is looks like a retarded wave. The retarded self-energy current wave can be written as,

$$Q_{1i} = \oiint\limits_{\Gamma} (\overrightarrow{E}^r_{1i} \times \overrightarrow{H}^r_{1i}) \cdot \hat{n} d\Gamma \tag{52}$$

The collapsed wave can be written as

$$Q^c_{1i} = \oiint\limits_{\Gamma} (\overrightarrow{E}^c_{1i} \times \overrightarrow{H}^c_{1i}) \cdot \hat{n} d\Gamma \tag{53}$$

Where $\overrightarrow{E}^c_{1i}$, $\overrightarrow{H}^c_{1i}$ are collapsed field for the emitter. Q^c_{1i} is collapsed mutual energy current of the emitter. We assume the field of the emitter are

$$\overrightarrow{E}_{1i} = \overrightarrow{E}^r_{1i} + \overrightarrow{E}^c_{1i} \tag{54}$$

$$\overrightarrow{H}_{1i} = \overrightarrow{H}^r_{1i} + \overrightarrow{H}^c_{1i} \tag{55}$$

We assume that

$$Q^c_{1i} = -Q^r_{1i} \tag{56}$$

Hence we have

$$0 = Q^r_{1i} + Q^c_{1i} = \oiint\limits_{\Gamma} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{1i}) \cdot \hat{n} d\Gamma \tag{57}$$

We can further assume that,

$$\nabla \cdot \overrightarrow{E}_{1i} \times \overrightarrow{H}_{1i} = 0 \tag{58}$$

We can further assume that

$$\overrightarrow{E}_{1i} \times \overrightarrow{H}_{1i} = 0 \tag{59}$$

This require that

$$\overrightarrow{E}_{1i} || \overrightarrow{H}_{1i} \tag{60}$$

Where "||" means "parallel to". Hence the electric field $\overrightarrow{E}_{1i}$ should parallel to the magnetic field $\overrightarrow{H}_{1i}$. This wave the field of the emitter is not vanish, but the total self-energy current, include retarded self-energy current and collapsed self-energy current, is vanish. Similar we can have,

$$\overrightarrow{E}_{2i} || \overrightarrow{H}_{2i} \tag{61}$$

The mutual energy current is possible still same as formula Eq.(54), i.e.,

$$Q_{12i} = \oiint\limits_{\Gamma} (\overrightarrow{E}^r_{1i} \times \overrightarrow{H}^a_{2i} + \overrightarrow{E}^a_{2i} \times \overrightarrow{H}^r_{1i}) \cdot n d\Gamma$$

That means the collapsed field $\overrightarrow{E}^c_{1i}$ and $\overrightarrow{H}^c_{1i}$ do not join the mutual energy current to transfer energy. But it is also possible that this collapsed field also

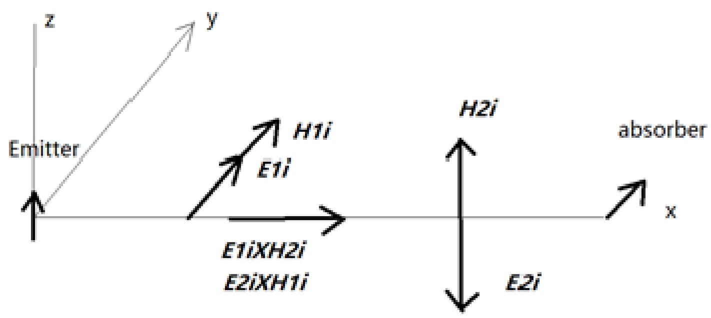

Figure 8: The photon model. The current of the absorber must be perpendicular to the current of the emitter. The electric field and the magnetic field of the emitter must have the same direction. The electric field of the absorber has the in the direction of perpendicular to the current of the emitter.

join the mutual energy current to transfer energy. In this situation, we actually assume the emitter and absorber can have send the parallel field to the space. If this kind field exist, the mutual energy current can be redefined as,

$$Q_{12i} = \oiint_{\Gamma} (\overrightarrow{E}_{1i} \times \overrightarrow{H}_{2i} + \overrightarrow{E}_{2i} \times \overrightarrow{H}_{1i}).nd\Gamma \tag{62}$$

Figure 8 shows the photon model corresponding to the parallel fields. The electric field and the magnetic field are parallel to the emitter and also to the absorber.

About the field collapsed $\overrightarrow{E}_{1i}^c$, $\overrightarrow{H}_{1i}^c$, it is possible some electromagnetic filed satisfies Maxwell equation. But if Maxwell equations,

$$\nabla \times \overrightarrow{E}_{1i}^c = -\mu\partial \overrightarrow{H}_{1i}^c \tag{63}$$

$$\nabla \times \overrightarrow{H}_{1i}^c = \epsilon\partial \overrightarrow{E}_{1i}^c \tag{64}$$

do not support this collapsed field the collapsed field perhaps satisfies time reversed Maxwell equation which is defined as flowing, where $\partial = \frac{\partial}{\partial t}$.

$$\nabla \times \overrightarrow{E}_{1i}^c = \mu\partial \overrightarrow{H}_{1i}^c \tag{65}$$

$$\nabla \times \overrightarrow{H}_{1i}^c = -\epsilon\partial \overrightarrow{E}_{1i}^c \tag{66}$$

The time reversed Maxwell equation is obtained through substituting $t = -t'$ to Maxwell equations Eq.(63,64), and then replace t' and t. It also can be obtained by substitute $[\epsilon, \mu] = [\epsilon', \mu']$ to the Maxwell equation and the replace $[\epsilon', \mu']$ with $[\epsilon, \mu]$.

Any wavy we need the collapsed field produce a self-energy $Q^c_{1i} = \oiint_\Gamma (\overrightarrow{E}^c_{1i} \times \overrightarrow{H}^c_{1i}).\hat{n} d\Gamma$ which is point to the emitter and also can synchronized with the original self-energy current field $Q^r_{1i} = \oiint_\Gamma (\overrightarrow{E}^r_{1i} \times \overrightarrow{H}^r_{1i}).\hat{n} d\Gamma$ and have opposite values, i.e.

$$Q^c_{1i} = -Q^r_{1i} \tag{67}$$

For the absorber, there is similarly discussions. It will be not shown here.

6.5 Summary

In this section we have introduced 3 methods to deal with the self-energy current 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. If the metal container is a wave guide, the self energy can also be sent from emitter to the absorber. In very complicated situation if the metal container is not like a wave guide, the self-energy is difficult to be sent from emitter to the absorber.

Hence we made another assumption. Another is that the transfer of self-energy doesn't have any contribution to the energy transfer. Self-energy current items are canceled. 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 the 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.

We also introduced another possibility that the self-energy current is collapsed back to the emitter and absorber. In this situation it is possible the collapsed field also join to the field to produce the mutual energy current. The collapsed field should be possible to synchronized to the original retarded wave for the emitter or the original advanced filed of the absorber. In this situation the electric field and the magnetic field of the emitter is parallel to each other. The electric field and the magnetic field of the absorber is also parallel to each other.

J. Cramer introduced the concept of continually collapse that means 3D wave continually collapse to a 1-D wave [3-5][4, 5]. In the authors' photon model, the energy transfer through the mutual energy current 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 wave 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.

Among the 3 method, we also mentioned one method the idea (c) in which the self-energy current collapsed. However here the collapse process is still a electromagnetic field phenomenon which satisfies the Maxwell equation.

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 the macrocosm field 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.

The macrocosm Poynting theorem is the result of the contribution of thousands mutual energy current. The macrocosm Poynting theorem has nothing to do with the self-energy current of the photon.

7 Polarization or spin of the photon

In the quantum physics, it is said the photon has spin, the photon have the energy $E = \nu h$, where ν is the frequency, h is plank constant. This formula cannot obtained from traditional Maxwell electromagnetic field theory. This should be the result of quantum physics. The emitter and absorber can only receive and transmit package energy νh. But with the mutual energy theorem it is clear that how the energy is transferred in free space.

It is similar, it is said the the angular momentum of the spin of the photon can only be $J=\hbar$, where $\hbar=\frac{h}{2\pi}$. This result cannot be obtained from the electromagnetic field theory. This is the result of the emitter and absorber. The emitter and absorber can only change their angular momentum as integer times of $\hbar$, hence photon can only have the spin momentum of $J=(-1,0,+1)\hbar$. The concept of spin is related the the concept of polarization. The electromagnetic field theory should be possible to offer how the linear and circular polarization of filed all be possible.

According the discussion of foregoing section about the mutual energy current we can offer 2 kind of polarization model for photon.

7.1 TE and TM mode of electromagnetic field

According to the foregoing theory of mutual energy current, the energy is transferred by mutual energy current. The field of the mutual energy current is looks like the wave in a wave guide. The two ends of this wave guide are two sharp tips. The middle of the wave guide become very wide. The wave inside the this so called mutual energy current wave guide can also have TE and TM mode of waves like normal wave guide. Hence there are two kind of mutual energy current

$$Q_{12i}^{TE}=\oiint_{\Gamma}(\overrightarrow{E}_{1i}^{TE}\times\overrightarrow{H}_{2i}^{TE}+\overrightarrow{E}_{2i}^{TE}\times\overrightarrow{H}_{1i}^{TE})\cdot\hat{n}d\Gamma$$

$$Q_{12i}^{TM}=\oiint_{\Gamma}(\overrightarrow{E}_{1i}^{TM}\times\overrightarrow{H}_{2i}^{TM}+\overrightarrow{E}_{2i}^{TM}\times\overrightarrow{H}_{1i}^{TM})\cdot\hat{n}d\Gamma$$

where $\overrightarrow{E}_{1i}^{TE},\overrightarrow{H}_{1i}^{TE}$ are TE wave of the emitter. $\overrightarrow{E}_{1i}^{TM},\overrightarrow{H}_{1i}^{TM}$ are TM wave of the emitter. It is same to the absorber there are also TE and TM wave. The TE and TM wave are perpendicular to each other. Hence the TE and TM wave can produce the the linear and circular polarization. The circular polarization can cause the photon spin.

7.2 Electric field and magnetic field parallel to each other

In last section Figure 8 has show, it is possible that the electric field and the magnetic field of the emitter are parallel to each other. In this situation the self-energy current vanishes (actually the collapse self-energy current cancel the original self-energy current. The total self-energy of the original self-energy current and the collapsed self-energy current vanishes). But the electric field and magnetic field of the emitter or absorber doesn't vanish. In this time the electric field must parallel to the magnetic field, see Figure 8. The mutual energy current there is,

$$Q_{12i}=\oiint_{\Gamma}(\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}+\overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i})\cdot\hat{n}d\Gamma$$

We assume that the current of the emitter is at the direction of $\hat{z}$ and the absorber is at the direction of $\hat{x}$, see figure 8. This can guarantee the two magnetic fields $\overrightarrow{H}_{1i}$ and $\overrightarrow{H}_{2i}$ are perpendicular. If the above two magnetic field are perpendicular, the electric field $\overrightarrow{E}_{1i}$ and $\overrightarrow{E}_{2i}$ will also be perpendicular or at least close to perpendicular. there are two items in the above formula, $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}$ and $\overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i}$, From Figure 8 we know along the line of from emitter to the absorber, $\overrightarrow{E}_{1i}$ just perpendicular to $\overrightarrow{E}_{2i}$, this made them perfectly to build a polarized field. If $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}$ has the same phase with the item $\overrightarrow{E}_{2i}\times\overrightarrow{H}_{1i}$, we obtain a linear polarized field. If the two items have 90 degree in phase difference, we will obtain a circular polarized field. If it is circle polarization, then it can be seen as spin. $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i}$ and $\overrightarrow{E}_{2i}\times\overrightarrow{H}_{2i}$ to produce the polarization.

Now the above model tells us the two electric fields $\overrightarrow{E}_{1i}$ and $\overrightarrow{E}_{2i}$ are perpendicular if the current of absorber is perpendicular to the current of the emitter. It is interesting to notice this two items $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{2i}$ and $\overrightarrow{E}_{1i}\times\overrightarrow{H}_{1i}$ 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 [17]. 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

We often say photon has spin. The spin angular momentum is 0 or $\pm\hbar$. This perhaps is because the atom or electron system can only loss or increase 0 or $\pm\hbar$ amount of

8.1 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 can be done only by the mutual energy current.

8.2 Self-energy current theorem

Self-energy currents of the emitter and absorber cannot vanish, we need self-energy current to cooperate with the mutual energy current to send the energy from the emitter to the absorber. The self-energy current is sent to infinity. But after the energy transfer process finish, the self-energy current must return to their sources, otherwise, the system with emitter and absorber will lose the energy, and this energy is sent to outside of our universe, that is not possible. There are 3 possibility to self-energy current.

(a) The retarded self-energy current of the emitter is sent to infinity and the advanced self-energy current of the absorber is sent to the infinity. Hence the absorber obtains the energy from the self-energy current. The self-energy current and the mutual energy current each has contributed half of energy transferring from emitter to the absorber.

(b) The retarded wave of the emitter is canceled by the advanced wave of the emitter. The advanced wave of the absorber is canceled by the retarded wave of the absorber. Hence, the self-energy current of emitter and absorber doesn't transfer any energy.

(c) the retarded self-energy current of the emitter collapse back to the emitter. The advanced self-energy current collapse back to the absorber. The self-energy currents do not have any contribution to the energy transferring from emitter to the absorber.

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.

8.3 Photon current

In (b) of the last subsection, the emitter and absorber all sends retarded wave and advanced wave. To make things simple, we can assume the emitter has a retarded current and an advanced current. The retarded current only produces retarded wave. The advanced current only produces advanced wave. It is same to the absorber. The absorber has an advanced current and retarded current. The advanced current of the absorber only produces advanced wave. The retarded current of the absorber only produces the retarded wave. The advanced self-energy current of the emitter/absorber can cancel the retarded self-energy current of the emitter/absorber. We can assume that the retarded current of the emitter/absorber is equal to the advanced current of the emitter/absorber, but the two current equal each other is not obligatory.

8.4 The electric and magnetic fields

In the subsection 8.2, even the self-energy currents cancel each other, the electric and magnetic fields of the emitter and the absorber do not vanish. For example, if electric field and magnetic field is parallel to each other, they do not vanish and have no contribution to the self-energy current. The electric and magnetic field not vanish will guarantee that the mutual energy current can transfer energy.

8.5 Poynting theorem

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 possible all canceled and hence has no any contribution to the macrocosm self-energy current. The microcosm mutual energy theorem is the foundation to the macrocosm Poynting theorem. The mutual energy theorem is more fundamental compare to the Poynting theorem. The macrocosm field of infinite more photons satisfies Poynting theorem means this field also satisfy Maxwell equations. We have succeessfully derived Maxwell equations in macrocosm from our photon model in microcosm.

8.6 The probability interpretation

The probability interpretation of quantum physics or the Copenhagen interpretation of quantum physics is based the theory of divergence wave. The divergence wave is because of the macrocosm Poynting theorem. After we know the microcosm Poynting theorem is caused by the infinite contributions of the mutual energy current of the photons, we have find the reason of the Copenhagen interpretation for the photon and the quantum. If we use Poynting energy current to describe the energy current of the photon which is mutual energy current, Poynting theorem can only offer a probability for the mutual energy current. Here the field of macrocosm satisfies the Poynting theorem and the field of microcosm satisfies the mutual energy theorem. All this kind filed are physics fields, no any field here are mathematical field like Copenhagen interpretation.

8.7 Polarization and spin theorem

The wave for mutual energy current very like to transfer in a wave guide, this wave guide has very special shape, it has two ends with very sharp tips, it is very wide in the middle. This wave guide is same as the normal wave guide can transfer TE and TM waves. The two electric fields $\overrightarrow{E}^{TE}$ and $\overrightarrow{E}^{TM}$is perpendicular to each other and hence can transfer linear and circular polarized waves.

There is also another possibility, that 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 in the above two situations, the absorber plays an important role similar to the emitter. This is the really reason for the experiment of delayed choice[7, 17]. In this theory any polarization for example circle polarization, linear polarization and eclipse polarization are all allowed. The authors do not oppose the concept the polarization of photon is only left/right circle polarization. But this theory is a classical electrical theory and hence can not derive quantum effect for the polarization. This theory only tell it is possible to have polarization for photons.

8.8 Synchronization theorem

The mutual energy current must synchronized. That means only when the retarded wave of the emitter reaches the absorber, in this particle time the absorber just sends its advanced wave out, the two waves 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 current 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 waves, the directions of current of the absorber and emitter, all this conditions are satisfied, the mutual energy current can happens. The photon is just this mutual energy current. The Poynting theorem in macrocosm offers the the possibility the photon will appear in which place. There is the possibility that two or more absorbers satisfy the above condition in the same time. However, we assume this possibility is very low. If two absorbers satisfy the same condition why only one can win and to produce the mutual energy and become a photon? John Cramer introduced the concept of transaction [4, 5]. However why has this transaction. This question is still open.

8.9 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 mathematical deformation of the mutual energy theorem. Mutual energy theorem is actually more fundamental compare 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. In one situation, the self-energy current has contribution to the energy transfer of the photon. The emitter send the retarded energy to the infinity and the absorber send negative energy energy to the infinity. This make the self-energy carry part of energy from emitter to the absorber. The mutual energy current also transfers energy. Self-energy and mutual energy each carry half-energy from emitter to the absorber.

In another situation, we have assumed that 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 in macrocosm are the contribution of all mutual energy current of infinite photons. In microcosm, the self-energy current which is the energy current corresponding to Pointing vector has no contribution to energy transferring. 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 situation the wave for mutual energy current can be seen as the wave in a special guide, which has two very sharp tips in the two ends, and very wide in the middle. This wave guide can support TE and TM waves. The linear and circle wave polarization can be supported by this TE and TM waves.

Another situation is the self-energy current is collapsed back from infinity. Hence, the mutual energy current is the only one can transfer energy. Since the self-energy current collapses, the total self-energy current vanishes, but the electromagnetic field did not vanishes, the electric field is parallel to the magnetic field. 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 models is derived from electromagnetic field with Maxwell theory, but it is possible also suit the wave of other particles, for example electrons.

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