

Transformation for the energy flux of the electromagnetic wave

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The quantum mechanical model of electromagnetic waves is considered, in which the photon, as a particle, propagates with the speed of light, while the wave function of the photon spreads out with an infinite speed. The Lorentz transformation for the energy flux of electromagnetic wave is obtained while assuming the Galilei transformation for the space and time. The energy of the electromagnetic wave also follows the Lorentz transformation with the volume restricting the wave train not following any transformation.

Keywords: energy flux of electromagnetic wave, Lorentz transformation, Galilean invariance

There is a fundamental conflict between quantum mechanics and special relativity. The latter claims Lorentz invariance which relies on the assertion that the speed of all physical processes is restricted with the speed of light. On the contrary, quantum mechanics admits the

wave function spreading out with an infinite speed. The existence of the wave function implies Galilean invariance. The free will theorem was proven [1] from which it follows that any theory admitting wave function collapse cannot be made relativistically invariant. The phenomenon of entanglement gives an example of the wave function defined instantaneously between two space-like separated states. Quantum correlations between two space-like separated states detected in Bell experiments, e.g. [2] and references therein, suggest a violation of relativistic local causality as well as time ordering thus favouring an infinite speed of transmission of phase information. In [3] several signaling scenarios with the use of entanglement are considered. In [4] an experiment on faster-than-light communication via the collapse of the quantum wave function is proposed. Also, the results of recent experiments on the measurement of the speed of propagation of the bound magnetic field [5,6] favour an infinite speed of transmission of energy in the near zone. All this makes it reasonable to reconsider special relativity such that to admit the quantum mechanics wave with an infinite speed.

Consider the following paradox [7]. The energy of the plain electromagnetic wave is given by

$$\varepsilon = SV = EHV \quad (1)$$

where $S = EH$ is the energy flux, E , H are the electric and magnetic field respectively, V is the volume restricting the wave train. According to the special relativity [8] the electric and magnetic fields follow the Lorentz transformation $E \propto LT$, $H \propto LT$ hence the energy flux follows the square of the Lorentz transformation $S \propto (LT)^2$ while the volume restricting the wave train follows the reciprocal Lorentz transformation $V \propto (LT)^{-1}$. As a result, the energy of the electromagnetic wave follows the Lorentz transformation $\varepsilon \propto LT$.

Let an observer in the rest frame determine the energy of the electromagnetic wave emitted in the moving frame

$$\varepsilon_{ap} = S_{ap} V_{pr} \quad (2)$$

where indices ap , pr stand for apparent and proper respectively. That is an observer determines the apparent energy of the electromagnetic wave in the moving frame through the apparent energy flux of the electromagnetic wave in the moving frame and the proper volume in the rest frame. It is worth noting that the measurement procedure does not allow one to determine the apparent volume restricting the wave train. The special relativity [9] is based on the assumption that the proper values are the same in all inertial frames. The apparent and proper values in the moving frame are related by the Lorentz transformation with the prime designating the apparent value, the proper value being denoted by no prime. We come to the expression for the apparent energy of the electromagnetic wave being different from the standard one. In view of eq. (2) the energy flux of the electromagnetic wave and the energy of the electromagnetic wave follow the same Lorentz transformation with the volume restricting the wave train not following any transformation. This signifies that the measurement procedure requires the Galilean invariant volume restricting the wave train, i.e. the Galilei transformation for the length and time. Thus, the measurement procedure requires transformations for the energy flux of the electromagnetic wave and for the volume restricting the wave train other than those given by special relativity. We come to the contradiction.

Also [7], the required transformation for the energy of an electromagnetic wave derived using the Lorentz transformation for the corresponding electric and magnetic fields is not found in the case when the velocities of the wave and the moving frame are transverse.

It was suggested [7] that only one of the fields follows the Lorentz transformation hence the energy flux of the electromagnetic wave follows the Lorentz transformation. This meets both the foregoing measurement procedure constraint and the problem with the energy of the electromagnetic wave in the frame moving transverse to the wave. In the present paper we shall derive the Lorentz transformation for the energy flux of the electromagnetic wave while assuming the Galilei transformation for the space and time.

In [10,11] the quantum mechanical model of electromagnetic waves is considered, in which the photon, as a particle, propagates with the speed of light, while the wave function of the photon spreads out with an infinite speed. For the stationary state of the photon the wave function of the photon spreads out with an infinite speed over the whole space. It is reasonable to think that such a wave does not transmit the energy but only the phase information. This admits of Galilean invariance of the phase of electromagnetic wave, which explains the null result of the Michelson-Morley experiment, without invoking Lorentz invariance [10]. For the non-stationary state of the photon the wave function of the photon spreads out with an infinite speed in the near zone [11]. This is in agreement with the results of recent experiments on the measurement of the speed of propagation of the bound magnetic field [5,6]. Within the framework of this model we shall study transformation for the energy flux of electromagnetic wave while assuming the Galilei transformation for the space and time.

Take the Euclidean space and absolute time of a privileged reference frame. We shall choose the cosmic microwave background radiation (CMB) as a privileged reference frame. Let an observer be at rest with respect to the CMB frame. Let the source of photons move along the x axis with the velocity v say approaching the observer. Consider a photon as a particle moving with the velocity c

with respect to the CMB frame independently of the velocity of the source. Define the spatial wave function of the photon spreading out instantaneously at the instant of emission (detection) of the photon. The spatial wave function of the photon yields distribution in space of the electric field E and the magnetic field H

$$\vec{E} = \vec{E}_0 e^{i\phi} \quad (3)$$

$$\vec{H} = \vec{H}_0 e^{i\phi} \quad (4)$$

with the phase

$$\phi = kr \quad (5)$$

where k is the wave vector.

Let the electric field E be directed along the y axis and the magnetic field H along the z axis. According to the standard point of view electric and magnetic fields in the electromagnetic wave are defined in the same point. Recall that the fields are defined through the vector potential \vec{A} as $\vec{E} = ik\vec{A}$, $\vec{H} = i\vec{k} \times \vec{A}$. The vector potentials defined on the y axis and on the z axis are separated by the distance $r = 1/2k$. It is reasonable to assume that the electric and magnetic fields are defined in different points separated by the distance $r = 1/2k$. From this there is a phase shift $r = 1/2k$ between the electric and magnetic fields that corresponds to the angle $\pi/2$ between the fields.

For the photon is of the size $r = 1/2k$ the centre and the end of the photon pass by a point of space at different instants of time. Let the centre of the photon take off the source at some instant of time and then move with the velocity c with respect to the CMB frame independently of the velocity of the source. After the time $t = 1/2ck$ lapses the end of the photon takes off the source. Due to the motion of the source at the instant of separation of the end of the photon from

the source the distance between the centre and the end of the photon is given by

$$x' = x - vt = x(1 - v/c). \quad (6)$$

In view of the foregoing assumption the decrease of the distance between the centre and the end of the photon yields the decrease of the phase between the electric and magnetic fields. As a result, the angle between the electric and magnetic fields increases. Let the magnetic field remain fixed along the z axis. Then, the electric field rotates at the angle $\beta = v/c$ to the y axis. The projection of the electric field on the y axis becomes

$$E'_y = E_y(1 - v^2/c^2)^{1/2}. \quad (7)$$

The projection of the electric field on the z axis yields an additional magnetic field

$$\Delta H'_z = -E_y \frac{v}{c}. \quad (8)$$

Then, the magnetic field becomes

$$H'_z = \frac{H_z}{1 - v/c}. \quad (9)$$

In view of eqs. (7,9), the energy flux of the electromagnetic wave in the moving frame is given by

$$S' = E'_y H'_z = S \frac{(1 - v^2/c^2)^{1/2}}{1 - v/c}. \quad (10)$$

We obtain the Lorentz transformation for the energy flux of the electromagnetic wave. Since we assume the Galilean invariant volume the energy of the electromagnetic wave also follows the Lorentz transformation. The energy flux of the electromagnetic wave eq. (10) meets the measurement procedure constraint eq. (2). Thus,

the quantum mechanical model of electromagnetic waves considered resolves the foregoing paradox.

In conclusion, the measurement procedure requires the energy flux of the electromagnetic wave and the energy of the electromagnetic wave to follow the same Lorentz transformation with the volume restricting the wave train not following any transformation. The quantum mechanical model of electromagnetic waves is considered, in which the photon, as a particle, propagates with the speed of light, while the wave function of the photon spreads out with an infinite speed. Within the framework of this model the Lorentz transformation for the energy flux of electromagnetic wave is obtained while assuming the Galilei transformation for the space and time. Since we assume the Galilean invariant volume the energy of the electromagnetic wave also follows the Lorentz transformation. Thus, the quantum mechanical model of electromagnetic waves considered meets the measurement procedure constraint.

Although we have obtained the Lorentz transformation for the energy of electromagnetic wave this does not mean Lorentz invariance because we use the Galilei transformation for the space and time. This signifies that the energy of electromagnetic wave is non-invariant. Elsewhere [12] the problem of non-invariance of electromagnetic wave is discussed. Also, it was shown [13] that the Faraday induction law is non-invariant.

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