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Modelling the Photon and Analyzing Its Electromagnetic and Physical Nature

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Abstract: This paper discusses and exposes the nature of the photon and its electromagnetic fields, as well as the mass of the moving photon. Formulas are derived that elucidate these findings and help to characterize the photon and its center of mass.
Keywords: photon, electromagnetic field, photonic mass.

It is known that electromagnetic radiation is spread at the velocity of light C. Its wavelength λ is changed in the range of $\lambda \approx (10^{7}......10^{-18})m,$ and frequency ν is changed in the range of $\nu \approx (10^{1}........10^{24}), s^{-1}$. The whole electromagnetic spectrum is divided into bands as shown in the table below:

Table 1

Electromagnetic spectrum bands

Bands	Wavelength, m	Oscillation Frequency, s^{-1}
1. Low- frequency band	$\lambda \approx (10^{7}.......10^{4})$	$\nu \approx (10^{1}.....10^{4})$
2. Broadcast band	$\lambda \approx (10^{4}......10^{-1})$	$\nu \approx (10^{4}......10^{9})$
3. Microwave band	$\lambda \approx (10^{-1}.....10^{-4})$	$\nu \approx (10^{9}.....10^{12})$
4. Relic band (maximum)	$\lambda \approx 1 \cdot 10^{-3}$	$\nu \approx 3 \cdot 10^{11}$
5. Infrared band	$\lambda \approx (10^{-4}.....7{,}7 \cdot 10^{-7})$	$\nu \approx (10^{12}.....3{,}9 \cdot 10^{14})$
6. Visible band	$\lambda \approx (7.7 \cdot 10^{-7}.....3.8 \cdot 10^{-7})$	$\nu \approx (3.9 \cdot 10^{14}....7.9 \cdot 10^{14})$
7. Ultraviolet (UV) band	$\lambda \approx (3.8 \cdot 10^{-7}.....10^{-9})$	$\nu \approx (7.9 \cdot 10^{14}......10^{17})$
8. Roentgen (X-ray) band	$\lambda \approx (10^{-9}.....10^{-12})$	$\nu \approx (10^{17}......10^{20})$
9. Gamma band	$\lambda \approx (10^{-12}.....10^{-18})$	$\nu \approx (10^{20}.......10^{24})$

The wavelength of maximal intensity in the electromagnetic realm of whole Universe is nearly one millimetre (relic band) [15], [16]. The law that governs this change of intensity resembles the law of intensity of radiation of a blackbody. That is why it has been ascribed to the cooling of the Universe [16].

One more hypothesis has appeared recently [3]. The relic radiation band corresponds to the limit of existence of the single photons [5], [6]. There are no single photons with a wavelength longer than the relic band. The maximum is formed here due to the fact that all photons with a wavelength less than that of the relic radiation would lose their energy gradually in the process of interacting with the atoms and the molecules of the environment in accordance with the Compton effect as they increase the wavelength and enter the relic band [9], [21], [22].

Now let us recollect an idea of the Indian scientist Bose, who in 1924 supposed that electromagnetic field is a collection of the photons, which he called an ideal photon gas [15]. Albert Einstein liked this idea very much and he translated his article from English into German and sent it to the journal of physics [15]. Figure 1 shows Allan Holden's concept concerning the formation of electromagnetic wavelengths by photon gas [18].

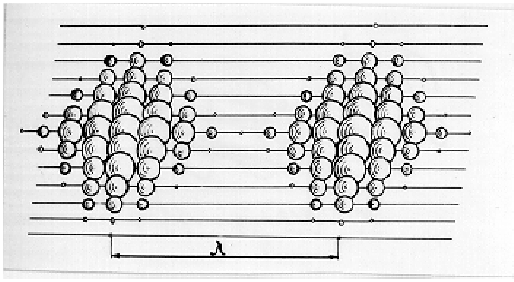


Figure 1. Diagram of electromagnetic wave with the length of λ after Allan Holden [18].

The diagram above is remarkable for the fact that according to Allan Holden, an electromagnetic wave is formed by the pulses of single photons, which are represented as the balls of different sizes by the author. The balls are the photons. The question thus arises: In what way does the size of a photon depend on the length of its wave?

Later on we will show that the wavelength λ of a single photon is equal to the radius r of its rotation, i.e. the wavelength of the photon determines the area of location of each separate photon in space [5], [6], [21]. In figure 1, radius of each ball is equal to the wavelength of the photon, and the distance between the pulses of the photons is equal to the wavelength (e.g., a radio signal).

Thus, the maximal wavelength of a single photon corresponds to the relic band, and the minimal wavelength corresponds to the gamma band. The wavelength of the photon is reduced by a factor of 10^{10}, and its frequency is increased by the same factor. As the photons of all bands move at the same velocity C, and as they form the waves of electromagnetic radiation, the velocity of electromagnetic radiation of all bands is the same [12], [21].

The question arises: which photons form low-frequency, broadcast and microwave bands? The waves (figure 1) of electromagnetic radiation can form the photons of all bands of the photonic part of the electromagnetic spectrum: relic, infrared, visible, UV, X-ray, and gamma bands. From an energy point of view it is more profitable to use the photons of the infrared band, because they are emitted by the surface electrons of the atoms of aerials. Excitation of the surface electrons on the upper energy levels of the atoms, which are near to the free state, is the most economical energy process [1], [21].

Thus, the hypothesis being suggested divides the electromagnetic spectrum into two classes: **photon** and **wave**. The photons are single electromagnetic formations; they are emitted by the atomic electrons. A collection of the photons emitted by the atomic electrons thus forms a field, which is called electromagnetic. It can be of a continuous or pulse nature (figure 1). The pulse of the photons forms the waves, whose behaviour is studied. The task of quantum mechanics is to find out the structure of the photon.

The attempts to explain the structure of the photon by using the equations suggested by Maxwell in 1865 fail [7], [18]. That's why we will try to find another approach to solve this problem. Let us begin with a detailed analysis of the existing mathematical models, which describe the behavior of the photon [21]. As a model of the photon remains unknown, the mathematical relations describing its behavior have not been derived, only postulated. The different relationships/natures of the photon are as follows [2], [7], [21]:

relationship to energy

$$E = m \cdot C^2 = h\nu, \tag{1}$$

relationship to velocity

$$C = \lambda\nu, \tag{2}$$

as a pulse

$$P = m \cdot C = \frac{h}{\lambda}, \tag{3}$$

to Planck's constant

$$h = m\lambda^2\nu = mr^2\nu, \tag{4}$$

to Heisenberg's inequality

$$\Delta P_x \cdot \Delta x \geq h, \tag{5}$$

and to the binding between linear frequency ν and angular frequency ω

$$\omega = 2\pi\nu. \tag{6}$$

The equation of Louis de Broglie, which describes the wave properties of the photon, can be added to these relations.

$$y = A\sin 2\pi(\nu t - x/\lambda). \tag{7}$$

Thus, the electromagnetic model of the photon should be such that all mathematical equations (1-7) describing its behaviour can be derived from the analysis of its movement.

The detailed analysis of the given mathematical relations has shown that the photon has a complex rotating electromagnetic structure, possessing wave and particulate properties while moving with constant velocity linearly. It has turned out that the mode of rotation and linear movement of the photon will be the most economic one from the energy point of view, only in case when the length of its wave λ is equal to rotation radius r [3, 5, 6].

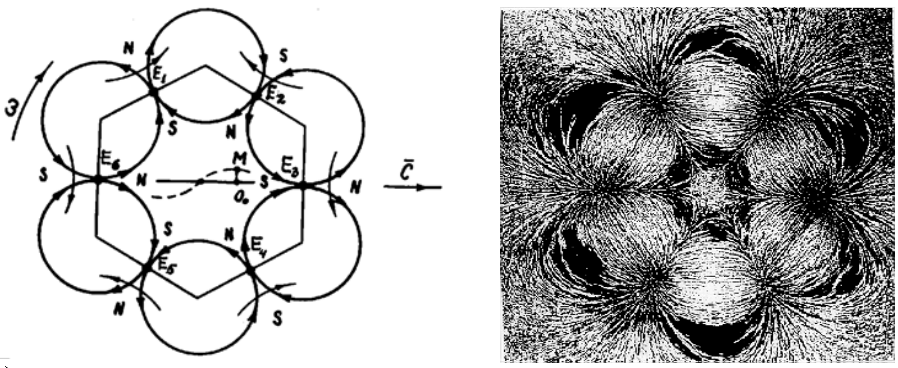
$$\lambda = r \tag{8}$$

Certainly, the process of finding as well as the substantiation of electromagnetic structure of the photon should be described in detail, but it would take dozens of the book's pages [2], [3], [5], [6], [8]. That's why we give the substantive diagram (figure 2) of the electromagnetic model of the photon. We will show how all of the main mathematical relations (1-7), that describe the behaviour of the photon, are derived from the analysis of the process of its motion.

The binding relation between the wavelength λ, which describes the photon's mass center and the radius r of its rotation (8), shows that the photon has six electromagnetic fields that are connected with each other according to the circular circuit.

$$\lambda = 2rSin\frac{\alpha}{2} = r \rightarrow Sin\frac{\alpha}{2} = \frac{1}{2} \rightarrow \alpha = \frac{\pi}{3} = 60^0. \tag{9}$$

The diagram of the theoretical and electromagnetic model of the photon are given in figure 2. As the photon in motion has mass [10], we have every reason to believe that it has a center of mass M . The peculiarity of the photon model is in the fact that its center of mass M does not coincide with geometrical center O_0 (figure 2a). It is the main reason why the photon has no state of rest. The detailed description of kinematics of the photon model is given in references [2], [3], [4], [8].



a) в)

Figure 2. Diagrams of the electromagnetic models of the photon: a) theoretical model; b) simulated one.

As the photon has the center of mass M , it is necessary to find the equations that describe the movement of this center. As the photon is polarized, the motion of its center of mass in the polarization plane should be describable. It is clear that Louis de Broglie's equation (7) cannot perform this function, as it is the only one; besides, coordinate x does not depend on time t . In reality, the changing coordinates of any object in space are functions of time. We have called this state the "space-matter-time unity". Thus, we need such equations, which could describe the oscillations of the center of mass of the photon within the framework of the space-matter-time unity in such a way that its average velocity would remain constant and equal to C . Our investigations [2], [3], [6], [8] have shown that only the equations of a shortened cycloid can meet the aforementioned requirements:

$$x = Ct + \frac{r}{2\pi}\sin 6\omega t; \tag{10}$$

$$y = \frac{r}{2\pi}\cos 6\omega t, \tag{11}$$

where $\omega = \alpha \cdot \nu = 60^0 \cdot \nu$.

The phase velocity of the photon's center of mass originates from:

$$V = \sqrt{(dx/dt)^2 + (dy/dt)^2} = \sqrt{V_x^2 + V_y^2} = 2C \cdot \cos 3\omega t. \tag{12}$$

A diagram of the change of phase velocity of the center of the photon masses is given in Figure 3.

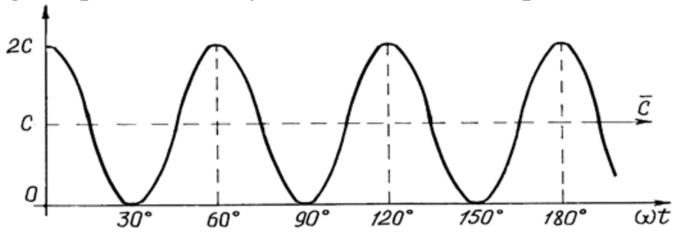


Figure 3. Diagram of phase velocity of the center of the photon masses.

It is clear that the phase velocity of the center of the photon mass is changed within the interval of the wavelength or the oscillation period from zero to $2C$ in such a way that its average value remains constant and equal to C .

Some investigators [13], [14] have noted that the photon has latent parameters. If it were possible to find them, all (1-7) mathematical relations describing its behaviour could be derived analytically. Let us try to find out these parameters.

As the photon model is rather complicated (figure 2), it is difficult to find the relations (1-7). But if we take into consideration that the photon has the plane of polarization, the movement of its center of mass in this plane, as well as the movement of the center of mass of its six electromagnetic fields, can be accompanied by rolling the conventional circumferences, of which the kinematic and energy parameters would be equal to the corresponding parameters of the photon. All parameters of the photon are rigidly connected with equations (10) and (11) of the motion of its center of mass [2], [3], [5], [6].

The center of masses M of the photon makes a complete oscillation in the interval of the length of its wave; that is why radius ρ_k (the first latent parameter) of the conventional circumference, describing the motion of this center in the interval of the length of one wave, will be determined according to the formula:

$$\rho_k = \frac{\lambda}{2\pi} = \frac{r}{2\pi} \quad . \tag{13}$$

The second conventional circumference will be the kinematic equivalent of the group motion of the centers of masses of the six electromagnetic fields of the photon. Its radius ρ_e (the second latent parameter) is determined from the condition of the rotation of the center of mass of each electromagnetic field through the angle $\alpha = 60^0$ in the interval of each length of its wave:

$$\rho_e = \frac{\lambda}{\alpha} = \frac{r}{\alpha}. \tag{14}$$

If angular velocity of the conventional circumference, which describes the movement of the center of masses M of the photon in relation to its geometrical O_o, is ω_0 (the third latent parameter) and angular velocity of the conventional circumference, which described the motion of the center of masses of each electromagnetic field, is ω (the fourth latent parameter) and the linear frequency is ν, the period of oscillations of the center of mass of the photon will be determined according to the formula:

$$T = \frac{1}{\nu} = \frac{2\pi}{\omega_o} = \frac{\alpha}{\omega}. \tag{15}$$

We have from it:

$$\omega_o = 2\pi\nu; \tag{16}$$

$$\omega = \alpha\nu. \tag{17}$$

While the amplitude A of oscillations of the center of mass M of the photon is determined according to the dependence [2],[3], [6]:

$$A = \frac{r}{2}(1 - \cos\frac{\alpha}{2}) = 0{,}067r. \tag{18}$$

DERIVATION OF MATHEMATICAL MODELS WHICH DESCRIBE THE BEHAVIOR OF THE PHOTON

The kinematic equivalence between the motion of the complicated electromagnetic structure of the photon and the conventional circumferences with radii ρ_k and ρ_e allows the derivation of the postulated mathematical relations (1-7), which describe its behavior. The latent unobserved parameters of the photon take part in the intermediate mathematical conversions and vanish in the final formulas.

As the small conventional circumference of radius ρ_k moves in the plane of rotation of the photon without sliding, the velocity of any of its points will be equal to the velocity of its center O_0 and the group velocity of the photon. Using relations (13) and (16), we have:

$$C = \omega_o \rho_k = \lambda \nu = r\nu, \qquad (19)$$

which corresponds to relation (2). The same result is given by the relations (14) and (17) of the second conventional circumference of radius ρ_e:

$$C = \omega \rho_e = \lambda \nu = r\nu. \qquad (20)$$

Now we see that the derivation of relation (2) not only agrees with the photon model (figure 2) and mechanics of its movement, but it also explains the particle and wave properties of the photon.

When deriving the relations (1), let us pay attention to the fact that the kinetic energy of the photons' motion (with mass) is equivalent to the kinetic energy of the conventional circumferences rolling with the same masses m, which are distributed equally in their length. The total kinetic energy of the conventional circumference will be equal to the sum of the kinetic energies of their translational motion and rotation with respect to the geometric center O_o:

$$E = \frac{mC^2}{2} + \frac{m\omega_o^2 \rho_k^2}{2} = mC^2 \quad . \qquad (21)$$

We would have the same result even if we use the second conventional circumference of radius ρ_e:

$$E = \frac{mC^2}{2} + \frac{m\omega^2 \rho_e^2}{2} = mC^2 \quad . \qquad (22)$$

By reducing the equation (21) to (1) we get:

$$E = \frac{mC^2}{2} + \frac{m\omega_o^2 \rho_k^2}{2} = mr^2\nu^2 = h\nu = mC^2 \quad , \qquad (23)$$

here

$$h = mr^2\nu \quad . \qquad (24)$$

It should now be clear that the latent parameters allow one to derive the main mathematical relations of quantum mechanics, which describe behavior of the photon, from the laws of classical mechanics. The conventional circumferences also allow us to determine the group pulse of the photons:

$$P = m\omega_o \rho_k = mr\nu = mC \quad , \qquad (25)$$

or

$$P = m\omega\rho_e = mC \qquad . \qquad (26)$$

From this it is easy to obtain the particle version of the Louis de Broglie's relation:

$$P = mC = \frac{mr^2\nu}{r} = \frac{h}{r} = \frac{h}{\lambda} \qquad . \qquad (27)$$

We can rewrite this as:

$$P \cdot \lambda = h \qquad . \qquad (28)$$

In the left part of the equation (28) we have the product of impulse P of the photon and its wavelength λ, and on the right we have Planck's constant h. Heisenberg's uncertainty relation originates from it:

$$\Delta P_x \cdot \Delta x \geq h \qquad . \qquad (29)$$

Let us now rewrite this inequality in an extended form:

$$m\frac{\Delta x}{\Delta t} \cdot \Delta x \geq mr^2\nu \qquad . \qquad (30)$$

As the photon displays its pulse in the interval of each wavelength, and its size is more than two wavelengths (figure 2), the values Δx and Δt inequalities (30) will each be more than 2. If we assume that $\Delta x \approx 2.3r$ and $1/\Delta t \approx 2.3\nu$ and substitute these values into inequality (30), we will have:

$$12.17 > 1 \qquad . \qquad (31)$$

Usually the inequality of the uncertainty principle is written as:

$$\Delta x \cdot \Delta P_x \geq \frac{h}{4\pi} \qquad , \qquad (32)$$

or

$$m\frac{\Delta x}{\Delta t} \cdot \Delta x \geq \frac{mr^2\nu}{4\pi} \qquad . \qquad (33)$$

If we assume that $\Delta x = \lambda = 2.3\lambda$ and $1/\Delta t = \nu = 2.3\nu$, we will obtain:

$$4\pi > 1, \quad \text{or} \quad 12.56 > 1 \qquad . \qquad (34)$$

In order to get the wave equation (7), it is necessary to move the description of the motion of the photon's center of mass outside the space-matter-time unity axiom. For this purpose, it is necessary to take either equations (10) and (11), for example here we will take equation (11). Here we would like to draw the attention of the reader to the fact that this operation automatically takes the process of the photon's center of mass outside the space-matter-time unity axiom:

$$y = \frac{r}{2\pi}\cos 6\omega t \qquad . \qquad (35)$$

Now to bring this equation to the form of(7), it is necessary to introduce the coordinate x into this equation using the phase difference for this purpose.

$$y = \frac{r}{2\pi}\cos(6\omega t - \omega_o t) \quad . \tag{36}$$

Taking into account that $\omega = \alpha\nu = 60^o \nu$ and $\omega_o = 2\pi\nu$, we have:

$$y = \frac{r}{2\pi}\cos 2\pi(\nu t - \nu t) \quad . \tag{37}$$

Let us designate $A_1 = \dfrac{r}{2\pi}$; and bear in mind that $\nu = \dfrac{V}{\lambda}$; $Vt = x,$ therefore:

$$y = A_1 \cos 2\pi(\nu t - x/\lambda). \tag{38}$$

Now it is clear that the main reason for the theoretical spreading of the de Broglie wave packet is explained by the independence of coordinate x from time t and the lack of correspondence of the de Broglie's equation with the space-matter-time axiom. Equations (10) and (11) have no such disadvantage.

Thus, we have derived all the basic mathematical models of quantum mechanics postulated earlier and describing behaviour of the photon. It should be noted that the photon model limits the accuracy of experimental information obtained, which is why we should acknowledge the correctness of Heisenberg's inequality [2], [3]. It is explained by the fact that the sizes of the photon can exceed the double length of their waves. This means that the photon cannot transmit a size of geometrical information that is less than double the length of their waves or two radii of rotation as it results from Heisenberg's inequality.

Some words about wave equations that describe behaviour of the photon. Before our interference into the behavior analysis of the photon, its wave properties have been described with the help of Louis de Broglie's equation and Schrodinger's equation. We have shown that Louis de Broglie's equation operates outside the space-matter-time unity axiom. Schrodinger's equation has the same drawback though [3], [6].

Thus, we leave at rest all of the mathematical formulas, which are used for describing the photon's behavior. We have nothing new here but we have confirmed trustworthiness of these formulas.

ON THE WAY TO ELECTRODYNAMICS OF THE PHOTON

It results from this that the mass of the photon is formed by its electromagnetic field. That is why the interaction between these fields provokes the internal Newtonian and electromagnetic forces (the forces that localize the photon in space and provide its motion with a constant velocity). That is why the main task of future photon research is to find these forces. As the equations of motion for the photon's center of mass and the centers of mass for its electromagnetic fields are known [2], [3], [5], [6], it is not difficult to determine the Newtonian forces. For example, in order to determine the forces influencing the center of mass of the photon, it is necessary to know the:

$$a_\tau = \frac{dV}{dt} = -6C\omega \sin 3\omega t. \tag{39}$$

Tangential force F_τ influencing the photon's center of mass will be equal to:

$$F_F = m \cdot a_\tau = -6Cm\omega \cdot \sin 3\omega t = -2\pi \cdot \frac{mC^2}{\lambda} \cdot \sin 3\omega t. \qquad (40)$$

Normal acceleration a_n of the center of masses of the photon:

$$a_n = \frac{V^2}{A} = \frac{V^2}{0{,}067r} = \frac{4C^2}{0{,}067r} \cdot \cos^2 3\omega t. \qquad (41)$$

The normal or centrifugal force influencing the photon's center of mass:

$$F_n = \frac{4mC^2}{0{,}067r} \cdot \cos^2 3\omega t. \qquad (42)$$

The full acceleration of the photon's center of mass:

$$a = \sqrt{a_n^2 + a_\tau^2} = \sqrt{36C^2\omega^2 \sin^2 3\omega t + \frac{16C^4}{(0{,}067r)^2} \cos^4 3\omega t} \;. \qquad (43)$$

This results in the force influencing the photon's center of mass:

$$F = m \cdot a = m \cdot \sqrt{a_n^2 + a_\tau^2} = m \cdot \sqrt{36C^2\omega^2 \sin^2 3\omega t + \frac{16C^4}{(0{,}067r)^2} \cos^4 3\omega t} \;. \qquad (44)$$

Obviously, it is enough to think that the way to the electrodynamics of the photon are opened, but it is not that easy. Certainly, the photon model provokes a large number of new questions and requires new answers for the numerous results of the experiments in which the behavior of the photon is registered. Nearly a hundred of answers for such questions are available in the books [3], [5], [6]. We give a part of them here. But prior to it, I would like the reader to pay attention to the essence of dimensionality of Planck's constant [11]:

$$h = m\lambda^2\nu = mr^2\nu\left(\frac{kg \cdot m^2}{s}\right) = const. \qquad (45)$$

In SI system this dimensionality corresponds to the equal notions of modern physics and mechanics: angular momentum, moment of momentum, and spin. It results from this that the law of conservation of angular momentum governs the constancy of Planck's constant. It also follows that if the sum of external forces influencing a rotating body is equal to zero, then the angular momentum h (momentum of momentum, spin) of that body remains constant all of the time.

ANALYSIS OF EXPERIMENTAL RESULTS

1. *Why do the photons fail to exist at rest?* Because the center of photon mass M (figure 2) never coincides with its geometrical center O_o. This lack of coincidence will create asymmetry between the electromagnetic forces of the photon and forms a state of unstable equilibrium, which causes its movement.

2. *Why is the photon wavelength reduced when its mass (energy) is increased?* Because the law of conservation of angular momentum $h = mr^2\omega = const$ governs this process. When mass m of the photon is increased, the density of its electromagnetic fields is increased as well (figure 2), which influence the center of mass of these fields. It leads to the reduction of radius r of the photon's rotation, which is always equal to its wavelength λ. But as radius r in the expression of Planck's constant is squared, photon oscillation frequency ν should also be increased in order to preserve constancy of Planck's constant. Due to this fact, a small alteration in the mass of the photon changes its rotational radius and frequency in such a way that angular momentum (Planck's constant) remains constant. Thus, photons of all frequencies preserve their electromagnetic structure, frequency, and wavelength in such a way that $m\lambda^2\nu = h = const$. This means that the law of conservation of angular momentum governs the principle of this alteration.

3. *Why do the photons of all frequencies move in vacuum with equal speed?* The alteration of frequency ν of the photons is a consequence of the alteration of their mass m, which in turn changes the density of the electromagnetic fields of the photon, leading to the change of radius r of its rotation. The aforementioned changes take place in such a way that the product of frequency ν and wavelength λ remain always constant for photons of all frequencies and is equal to $\lambda \cdot \nu = C$ (2). It is important to pay attention to the fact that the velocity of the center of mass M of the photon (figure 2) is changed during the interval of the wavelength in such a way that its average value remains constant and equal to C (figure 3).

4. *Why do the photons possess the properties of a wave and of a particle at the same time?* As the electromagnetic fields are closed along the round contour, the photon obtains the properties of a particle and the oscillations of the center of mass M of the particle relative to its geometrical center O_0 thus imparting wave properties to it (figure 2). As the photon's surface is not a spherical one, but rather a complicated curvilinear from interacting with the objects, it forms diffraction and interference pictures that will be distributed non-randomly but in accordance with the surface form and the interaction laws, which result from this.

5. *Why are the photons polarized?* They rotate in one plane, and the centrifugal forces of inertia influencing the centers of the mass of the electromagnetic fields of the photon, increasing their radial dimensions and reduce those dimensions that are perpendicular to its plane of rotation. Due to it the photons acquire form, which is different from the spherical one and more resemble a flat one.

6. *Why do the photons possess no charge?* They consist of even quantity of direction of different electrical and magnetic fields thus making the total charge of the photon equal to zero.

7. *Why is angle of incidence of the photon equal to angle of reflection despite the rotation of the plane of orientation (photon polarization)?* When the photon contacts the reflecting plane, the photon is partially deformed and acquires the form, which is almost a spherical one. But this is not all. The calculations demonstrate that at the moment of reflection, the photon has no transverse component of a pulse. Thus, as the form of the photon is almost a spherical one at the moment of reflection, there is only a longitudinal pulse, yielding the conditions that form when the angle of incidence of the photon is equal to the angle of reflection despite of the orientation of its plane of rotation in the moment of reflection.

8. *Does the photon have the velocity of light after reflection or "birth" or does it move with acceleration at the beginning?* When reflected or born, the photon moves with accelerations as the

processes of birth and reflection are transient processes, during which it obtains the velocity limit after a definite quantity of oscillations.

9. *Does the photon lose energy during transition process?* Yes, it does mainly by transferring it to an object with which it interacts. Compton's effect proves it. Due to it, the wavelength of the reflected photon is increased. As it is clear from the relations $E = h\nu = m\lambda^2\nu^2 = mr^2\nu^2$, it is possible only when its mass m and oscillation frequency ν are reduced. The photon energy reduction is equal to the reduction of its mass, which leads to the reduction of the electromagnetic fields density and a reduction of electromagnetic forces, which compresses the photon; due to it, the photon's rotational radius is increased. Equality between the electromagnetic and centrifugal forces of inertia influencing the electromagnetic fields' centers of mass are restored due to the reduction of angular momentum ω of rotation of the photon's center of mass. The same phenomenon takes place when the photon is born. Infrared and UV displacement of spectral lines in the astrophysical observations are its proof [17], [19], [20].

10. *What is the nature of the radio wave band of the scale of electromagnetic radiation?* A radio wave band of radiation is a flux of photons, and a modelled radio wave is a flux of photonic pulses (figure 1).

11. *Why is the propagation distance of a surface radio wave increased with the increase of its length?* Due to the increase of the length of the radio wave, the number of the photons, which form the wavelength (figure 1) is increased, and the possibility of delivery of information by such a wave is increased, despite the fact that a part of the photons are disseminated by the environment, and a part of them being absorbed. If the wavelength is reduced, the number of the photons, which carry it, is also reduced, and the possibility of information delivery to the receiver is reduced.

12. *In which way does a radio wave with its length measured in kilometers transmit the information to a receiver that may only be several centimetres or less in length?* It is possible to transmit the information by a radio wave, which length that is measured in kilometers to a receiver many factors of magnitude smaller than the length of the radio wave due to the fact that it is only a set of single photons carry the wave. All that is needed is to stimulate the electrons of the receiver with a few photons (Figure 1) from the original set (waves) in a specific sequence.

CONCLUSION

The analysis of the structure of electromagnetic radiation shows that it is formed by numerous sets of the photons. Maxwell's equations describe the behavior of this set, and the equations of quantum mechanics that originate from the laws of classical physics, describe the behavior of each photon separately.

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