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New Justifications for the Ballistic Structure and Motion Scheme of Photons

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ABSTRACT

The work relates to the fundamentals of quantum physics and photonics, in particular to the formation of ballistic photons, as well as to the parameters of their structure and processes of their motion. The study of these problems is an important and urgent task for understanding the foundations of the material world, which has not yet been fully resolved. At present, a wide range of electromagnetic waves is referred to as photons or quanta of wave radiation. But it is necessary to highlight the waves of the optical range of 380 – 760 nm, associated with photons – the only massless physical particles in the material world. This led to an attempt to abandon photons as physical particles and replace them with wave radiation. In addition to the problem of mass, the problem of ballistic photons and the motion pattern is acute. Its solution is the main goal of the work performed, and new confirmations of the ballistic motion of photons as an electromagnetic wave and as a physical particle within the duality of its existence is its scientific novelty.

Research Methods: Since this work has the level of scientific discovery, for finding which strict methods have not yet been created, therefore, general principles of development of the theory of scientific knowledge were used, based on the laws of dialectics and consistency with the basic laws of physics. The author's research methodology was also used, based on the transition to the initial quantum level of the material world and the processes occurring at the same time.

New Results of the Work and their Discussion: It is shown that photons are dual matter-wave physical objects, in which the properties of an electromagnetic wave prevail when they move at the speed of light, and the properties of a material particle are manifested when they slow down or meet an obstacle. The rectilinearity of their movement reduces them to ballistic ones. In this case, photons are transformed into spherical waves of Planck thickness 4.05×10-35 m, with a transverse surface of the sphere of 1 steradian, the radius of which and half the length of its arc are equal to the wavelength of radiation λmax, and spherical waves rotate perpendicular to the vector of their motion. When reflected from a mirror surface, they turn inside out, preserving the previous direction of rotation, and a change in the vector of the direction of motion makes them antiphotons, in which the spin and direction of the right and left mapping change.

Conclusions: All photons are ballistic, from their emission to absorption or re-emission. Other types of photons and their motion by re-emission of energy make up an insignificant part of their total number. There are possibilities for experimental confirmation of the obtained results, to which all laboratories and researchers with such capabilities are invited.

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Introduction

The work relates to the fundamentals of quantum physics and photonics, in particular to the formation of ballistic photons, as well as to the parameters of their structure and processes of their movement. The study of these problems is an important and urgent task for understanding the foundations of the material world, which has not yet been fully resolved.

Photons or quanta of wave radiation currently include a wide range of electromagnetic waves [1]. However, it is necessary to single out waves of the optical range of 380 … 760 nm, perceived by the human eye, in order to avoid confusion between photons of visible light and quanta of electromagnetic radiation. This visible range was expanded at the end of the 19th century, after the experiments of Hertz in 1888, which proved the unity of light waves and other electromagnetic waves [2]. At present, these include waves from super-long 10^8 m to X-ray and γ-radiation waves of 10^{-16} m, the diagram of which is shown in (Figure 1), which has received wide distribution and recognition, which is confirmed by its inclusion even in Wikipedia materials [3].

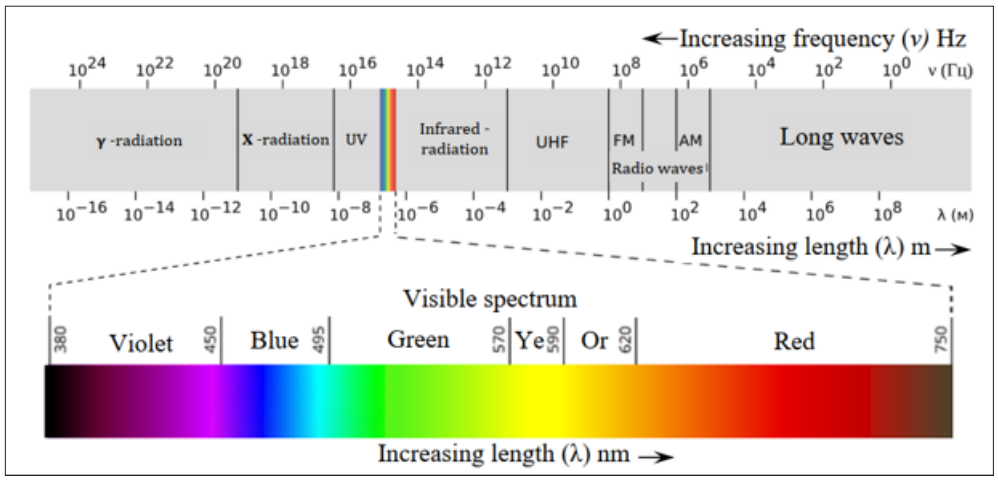

Figure 1: Modern Understanding of Wavelengths and Frequencies of their Oscillations within the Framework of Electromagnetic Radiation

However, in the author's work [4], this range was expanded to new wavelengths obtained in various real and theoretical physical processes [5,6]. The main feature of the new scheme of wave parameters is that it specifies strict limiting boundaries of the range of electromagnetic radiation with clarification of the zone of radio waves and ultra-high frequency waves (Figure 2).

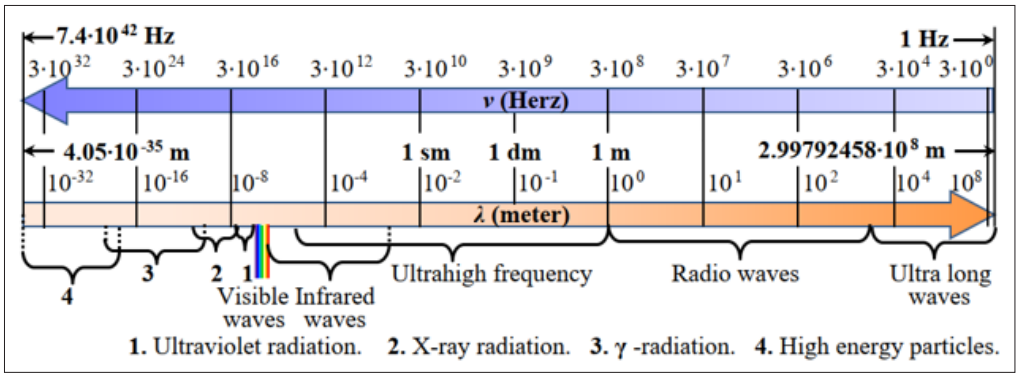

Figure 2: The Full Range of Wavelengths and Frequencies of their Oscillations in Electromagnetic Radiation

Establishing limiting values when there is an opinion about the infinity of the material world is an important scientific achievement. It was taken into account that the lower limit of the frequency of electromagnetic wave radiation is ν_{min} = 1 Hz, or 1 s^{-1}, since at lower frequency values the speed of light c = 029979258×10^9 m/s will be exceeded [6]. This contradicts the limit of the speed of all processes and phenomena in the material world, introduced in Einstein's special and general theories of relativity [7,8]. Within the framework of this limitation, the maximum possible wavelength of electromagnetic radiation is numerically equal to this speed *c*.

When determining the upper limit of wavelengths and their oscillation frequencies, it was taken into account that the limit of such parameters are Planck quantities: wavelength $\lambda_{min} = l_P$ (1) [5] and their oscillation frequency $\nu_{max} = \nu_P$ (2) [9]:

$$l_p = \sqrt{\frac{hG}{c^3}} = \sqrt{\frac{6.62607015\cdot10^{-34}\left(\frac{kg\cdot m^2}{s}\right)\cdot 6.67430\cdot10^{-11}\left(\frac{m^3}{kg\cdot s^2}\right)}{\left[0.299792458\cdot10^{9}\left(\frac{m}{s}\right)\right]^3}} = 4.05135\cdot10^{-35}\,(m), \quad (1)$$

$$\nu_G = \sqrt{\frac{c^5}{Gh}} = \sqrt{\frac{\left[0.299792458\cdot10^{9}\left(\frac{m}{s}\right)\right]^5}{6.67430^{-11}\left(\frac{m^3}{kg\cdot s^2}\right)\cdot 6.62607\cdot10^{-34}\left(\frac{kg\cdot m^2}{s}\right)}} = 7.39982\cdot10^{42}\left(s^{-1}\right). \quad (2)$$

where c – speed of light in vacuum: $c = 0.299792458\cdot10^{9}\,(\text{exactly})\frac{m}{s}$, [10].

h – Planck's constant [10]:

$h = 6.62607015 \cdot 10^{-34}\,(\text{exactly})\, J \cdot s = 6.62607015 \cdot 10^{-34}\,(\text{exactly})\, \frac{kg \cdot m^2}{s}$,

G – gravitational constant: $G = 6.67430(15) \cdot 10^{-11}\, \frac{m^3}{kgs^2}$. [10]:

The minimum period of radiation of such waves is t_{min} (3), which can also be obtained through the constants c, h, G, as the Planck time $t_{min} = t_p$ (4):

$$t_{\min} = \frac{1}{7.39982 \cdot 10^{42}\left(s^{-1}\right)} = 0.135138 \cdot 10^{-42}\,(s). \qquad (3)$$

$$t_p = \sqrt{\frac{hG}{c^5}} = \sqrt{\frac{6.62607015 \cdot 10^{-34}\left(\frac{kg \cdot m^2}{s}\right) \cdot 6.67430 \cdot 10^{-11}\left(\frac{m^3}{kg \cdot s^2}\right)}{\left[0.299792458 \cdot 10^{9}\left(\frac{m}{s}\right)\right]^5}} = 0.135138 \cdot 10^{-42}\,(s), \qquad (4)$$

For now, the values λ_{min}, t_{min}, v_{max} are theoretical, but they are obtained on the basis of only 3 fundamental physical constants: c, h, G according to strict physical dependencies, which makes them secondary constants of the material world. Considering the reality of the physical constants c, h, G, determined experimentally, there is every reason to believe that the secondary physical constants (1), (2), (4) found on their basis are also real physical quantities that will still be found in experiments [1]. But even now, high-energy cosmic particles can actually be carriers of such waves.

It should be taken into account that the accuracy of the gravitational constant G is the least compared to other physical constants, therefore its refinement continues with a large range of scatter of the obtained results. Taking this into account, in this work the averaged values of the minimum limiting wavelengths (5) and the period of their radiation (6), as well as their maximum frequencies (7) were adopted, which is acceptable in studies at the level of still only predicted results.

$\lambda_{min} = 4.05135 \times 10^{-35}$ m $\rightarrow 4.05 \times 10^{-35}$ m. (5)

$t_{min} = 0.135138 \times 10^{-42}$ s $\rightarrow 0.135 \times 10^{-42}$ s. (6)

$v_{max} = 7.39982 \times 1042$ s^{-1} $\rightarrow 7.4 \times 10^{42}$ s^{-1}. (7)

With further refinement of the value of G, parameters (5) … (7) will also be refined.

In the general range of electromagnetic waves (Figure 1 and 2), special attention is paid to visible light waves, since light, unlike the movement of other physical particles, can only move at the speed of light c, which introduces a relativistic aspect into this process, associated with the infinite value of mass during such movement.

Attempts to understand the nature of light have been made since ancient times. In ancient Egypt, the sun god Ra was worshiped [11]. In ancient Greece, fire was one of the foundations of the creation of the world; Pythagoras, Aristotle, and others studied the problem of light [12]. In the 1st millennium AD and in the Middle Ages, there were no major achievements in this area. A special contribution to the study of the nature of light was made only in the 17th century by the "atomist" of Pierre Gassendi and Isaac Newton, who proposed a corpuscular theory of light [13,14]. But they were preceded by the foundations of an alternative wave theory of light, laid down in the works of René Descartes and Robert Hooke [15,16]. However, Newton's authority gave great advantages to his theory, which faded into the background only at the beginning of the 19th century after the experiments of Thomas Young, Augustin Fresnel and Christiaan Huygens, who proved the wave nature of light [17-19]. In the 1860s, James Clerk Maxwell theoretically substantiated the electromagnetic basis of light waves, which was confirmed experimentally by Heinrich Hertz in 1888 [2,20]. It was only in the 20th century that it became possible to combine these two theories [1] but the final version of the unification is still disputed [1].

This is explained by the fact that at present the photon is recognized as the only massless physical particle in the real material world, which is due to its movement at the speed of light, at which, within the framework of the Lorentz γ-factor, its mass must be infinite [21]. Since mass is a real feature of all known physical particles (except for the hypothetical gluon, which has not been detected in an isolated state, but only inside physical particles), therefore, attempts have arisen to abandon the photon as a material physical particle, replacing it only with a wave [22]. However, this contradicts the general principles of dualism in the structure of the material world and experiments to determine the light pressure of Professor Lebedev, the photoelectric effect, substantiated by Einstein and the scattering of photons on electrons, discovered by Compton [1,23-25]. The justification of the mass and quantum structure of photons of light, as a wave and a physical particle, was also proposed in [4,26], and indirect signs of the presence of photon mass have already been revealed in 26 experiments cited in [27]. Without diminishing the importance of other studies on the problem of photon mass, their detailed analysis is not given, since it goes beyond the scope of the problems solved in this work.

The main focus of this paper is on the substantiation of ballistic photons of light and the scheme of their motion. The original substantiation was proposed in [28]. These include photons that move in a straight line before and after their absorption or deflection when passing through physical fields and boundaries of various media [1]. Like the substantiation of the dual structure and mass of the photon [4,26], its ballistic motion has caused a discussion at ResearchGate [29-31]. Discussion of the main provisions of this discussion is the main goal of the work being performed, and new confirmations of the ballistic motion of the photon as an electromagnetic wave and as a physical particle within the duality of its existence in the material world is the scientific novelty of the work being performed.

Research Methods

When choosing them, it was taken into account that this work has the level of a scientific discovery, for the detection of which strict methods have not been created [32,33]. Therefore, general principles of the development of the theory of scientific knowledge were used, based on the laws of dialectics [33,34] and consistency with the basic laws of physics [1]. The author's research methodology was also used, based on the transition to the initial level of the material world and the processes occurring in this case [35].

New Results of the Work and their Discussion: In further studies, it was taken into account that the presence of a relativistic photon mass is a problematic issue. However, the energy of light waves is strictly determined by the value (8) [1]:

$$E = h\nu = \frac{hc}{\lambda}(J). \qquad (8)$$

There cannot be a greater value of photon energy, since when it increases, the oscillation frequency of their waves increases adequately and their length decreases, which makes the original photons other photons. Therefore, the value of photon energy (8) is the maximum possible for waves of a specific "color", which allows it to be considered relativistic energy already taking into account the Lorentz γ-factor. In this case, the value of their mass will also be finite, within the framework of the law on the relationship between energy and mass of physical particles (9), which is the energy mass of photons (10), which on a strict physical basis also allows it to be considered relativistic mass [1]:

$$E = mc^2\,(J). \qquad (9)$$

$$m = \frac{h\nu}{c^2} = \frac{h}{c\lambda}(kg). \qquad (10)$$

The exclusion of infinite values of energy and mass of photons is explained by the fact that within the quantum foundations of the material world, there is no compression of physical objects to values less than (1), and the value of 0 length is jumped by a quantum jump in the interval (1), which was shown in [4,26,35]. Therefore, at the quantum level, there is no differential calculus, and the minimum Planck values l_p (1), t_p (4) are synonyms for mathematical *dl* and *dt*.

The main feature of ballistic photons is that they move in a straight line, which can be curved, for example, under the action of a gravitational field, if the photons have mass. Since the presence of photon mass has already been substantiated in [4,26,27], this problem is not considered further in the work being performed, the main attention is paid to ballistic photons and their motion options.

Within the duality of the existence of physical particles in the material world, the photon has a wave structure during its motion, and a substance particle, into which the waves are transformed at the moment of their deceleration upon encountering an obstacle. This strictly corresponds to the general characteristics of elementary particles of the material world, whose wave properties increase with the growth of their speed of motion, and with a decrease in this speed, the properties of the particle and substance are more pronounced [1]. Therefore, a photon, having in its motion the maximum possible speed equal to the speed c of light in a vacuum, is only a wave, and upon encountering an obstacle this speed is damped to 0 and it degenerates into a particle. At the stage of photon emission (for example, during the transition in an excited atom of an electron from a higher energy orbit to a lower one), it is also a particle, since, having received the energy impulse of the electron transition, it accelerates in the direction of its motion vector from zero speed to the speed of light. After this, the photon becomes only a wave, which allows us to conclude that only the "light" itself can move at the speed of light c, like an electromagnetic wave and all other electromagnetic waves. If their motion vector is not affected by external fields and other factors, it remains rectilinear, and the presence of the initial impulse of motion makes it inertial and ballistic.

That light waves move rectilinearly and radially from the radiation source in the direction of their initial motion vector was rigorously demonstrated by Newton [14]. This fact can be confirmed by the simplest experiments

- In the presence of smoke or dust particles in the path of the photons-rays of light,
- In the rectilinear movement of the target for receiving the photons-rays of light, for example, a sheet of paper in their path. More complex experiments are also possible.

Since the photon, as a physical particle, appears at the beginning and at the end of this rectilinear path and is an integral part of it, then this entire process and all stages of the photon motion are ballistic. Scattering photons are also ballistic if they are scattered by radial quanta from the radiation source. Within the framework of modern ideas about such motion of electromagnetic waves, they are depicted as spirals, examples of which are shown in Figure 3 [36]:

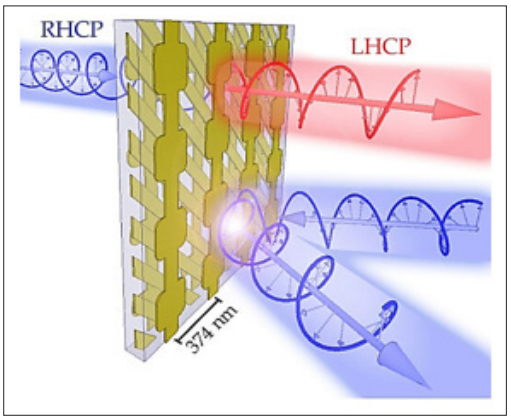

Figure 3: Modern Concept of the Motion of Light Waves and their Transformation when Meeting an Obstacle.

However, the motion of light waves in the form of continuous spirals contradicts the general quantum principles of radiation, proven by M. Planck in 1900, which requires the elimination of this drawback [37]. It was taken into account that within the framework of γ-relativism, with an increase in the speed of movement of physical particles formed by a clot of electromagnetic field closed in a ball, their sizes are compressed in the direction of their motion vector and their sizes increase in the radial direction to the motion vector. Such a transformation leads to a change in the original spherical structure of physical particles into an ellipsoid, which, upon reaching the speed of light c, is compressed along into a sphere of Planck thickness (1), and expands in the transverse direction to a surface of 1 steradian with a radius R_{max}, equal to the photon wavelength λ_{max} (Figure 4).

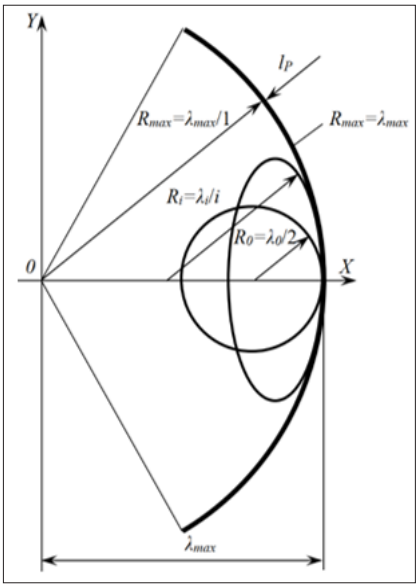

Figure 4: Scheme of Transformation of a Physical Particle and Formation of its Wave when approaching the Speed of Light.

Based on the proposed spherical wave of a photon of 1 steradian, its motion occurs in quantum jumps of wavelength λmax with rotation in the direction of the velocity vector υ, while the rotation can be associated with the gimlet rule, and the pulses of such half-waves have a quantum structure in the form of quantum jumps of a rectilinear shape (Figure 5).

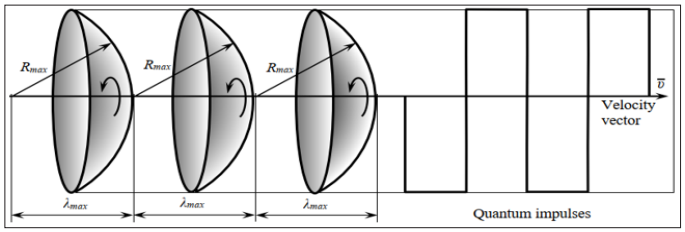

Figure 5: Scheme of the Motion of Spherical Transverse Waves of Light by Quantum Jumps and their Momenta.

Rotation ensures the stability of the waves during their motion. In this case, spherical Schrödinger wave fronts are actually formed [38] taking into account the Dirac transformations [39] for objects that have spin and move at high speed. But they are not infinite, but limited by the real parameters of the wavelength λ_{max} in space and the half-period of their radiation in time t_{max} (11):

$$t_{\max} = \frac{\lambda}{c}(s). \qquad (11)$$

In the wavelength range of visible light (0.380…0.760) ×10^{-6} m, this time will be value (12):

$$t_{(380...760)} = \frac{(0.380...360)\times 10^{-6}\,(m)}{0.299792458\times 10^{9}\left(m/s\right)} = (1.257...2.535)\times 10^{-15}\,(s). \qquad (12)$$

The quantum structure distinguishes photon waves from sound and similar waves, for the formation and transmission of which a molecular medium is used, since the laws of quantum mechanics do not apply to it and there are no restrictions on the size of the waves and the dissipation of energy for them. The quantum structure of photon waves also distinguishes them from the rays of light that make up a packet of photons, so their oscillation and movement differ from the oscillations of the "musical string" proposed by Yang [17], his physical model is acceptable for macro-level objects. There are "tubes" in the quantum motion of waves, but they do not have transverse vibrations that require energy, and rotation can be virtual and without energy expenditure with a quark hexagonal shape of spheres [4, 26]. Thus, the wave motion scheme shown in Figure 3 should be recognized as incorrect. Also, the currently used photon image schemes shown in Fig. 6 should be recognized as incorrect.

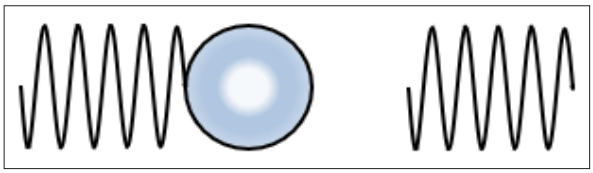

Figure 6: Traditional Images of a Photon as a Wave and an Elementary Particle.

A closer diagram is the interaction of waves within the framework of the Huygens-Fresnel principle [1]. When the spherical waves of a photon (Figure 4) meet a matte surface whose microroughness (roughness) is greater than the length λ_{max}, the waves are destroyed and absorbed by them. When meeting a mirror surface, the microroughness of which is less than the wavelength λ_{max}, the wave is successively reflected from all points of contact with the mirror and turns "inside out" in their central part (shown in red in the diagram shown in Figure 7) and then the wave moves in the direction of the reflection vector υ'.

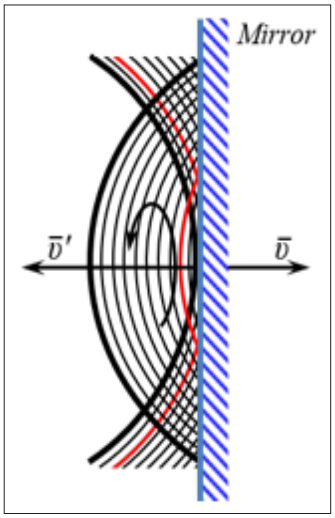

Figure 7: Diagram of Direct and Reflected Interaction of a Spherical Wave with a Mirror.

In this case, the rotation of spherical waves remains the same, and their motion vector changes direction, which transforms a photon into an antiphoton, and all reflected light rays change their structure from left to right (or vice versa), which is confirmed by mirror images of objects. This definition is correct, since a photon has no electric charge, like particles and antiparticles. Each phase of photon reflection occurs in quantum jumps of minimal magnitude $dl = l_P$ (1), which occurs during the Planck time $dt = t_P$ (4). Thus, the specified transformations occur with the speed of wave reflection υ_r, which is equal to the speed of light c (13):

$$\vartheta_\gamma = \frac{dl}{dt} = \frac{l_P}{t_P} = \frac{4.05135\times 10^{-25}\,(m)}{0.135138\times 10^{-42}\,(s)} = 0.299796\times 10^{9}\left(\frac{m}{s}\right). \qquad (13)$$

However, the full scope of the problem of light reflection requires separate studies that go beyond the problem of proving the ballistic nature of photons, which is solved in this work.

Further discussion at ResearchGate was connected with the denial of the very existence of ballistic photons and the processes of their motion by replacing them only with the process of re-emission with the sequential transfer of their energy [29-31]. However, the linearity of their motion before entering the re-emission zone within the framework of the schemes considered above proves their ballistic nature. It can be assumed that on single electrons or on other physical particles, the dimensions of which are smaller than the transverse spherical wave of a photon, their scattering in the form of the Compton effect is possible [25]. The process of re-emission of a photon on physical particles with the complete absorption and return of their energy raises doubts given the ratio of their dimensions, excluding complete contact according to the scheme of Figure 7. However, it is possible to admit the process of the wave bending around these particles without re-emission, with the initial wave turning inside out and merging after passing

an obstacle, which leads to the production of an antiphoton. The possibility of the bending of obstacles by light waves is confirmed by the experiment with two slits, the zone between which is an obstacle. In this case, antiphotons, mirror-reflected further along their path, will again become simply photons and will lose the right-left orientation they received after being turned inside out, which can be determined experimentally if such an experiment is developed.

For the re-emission of photons with a consistent transfer of energy, a real physical environment is needed. Intergalactic, interstellar and interplanetary vacuums do not contain a sufficient number of physical particles necessary for the full implementation of this process. Replacing the vacuum with a hypothetical "ether" is unfounded, since its real physical parameters are unknown - energies, physical processes, their forces, phenomena and effects. Therefore, they ascribe to the ether those capabilities that its users "desire". If such a process occurs at the interface of different physical environments, for example, plasma, as Peter Jackson suggests [29-31], but there is no strictly proven data that plasma fills the entire space of the Universe. At the same time, it moves at a lower speed than the speed of light, and "lags behind" the boundaries of the Universe, and its creation requires energy and processes, incl. for the formation in plasma of jets with different densities, which do not exist in the Universe. All plasma flows known in astronomical observations have their sources and special conditions for separating the density of their internal environments, there is also no evidence of the primacy of the appearance of plasma from unclear processes and sources.

In this case, the real process of re-radiation can be substantiated by the following working hypothesis:

- All phenomena and effects of the process must occur within the framework of real physics, based on specific energies and forces, substantiated by the principles of least action.
- Unlike abstract mathematical justifications, in the real world there are no physical processes that occur instantly, in zero time, they require a really substantiated time.
- According to the diagram in Fig. 7 (but without wave reflection), in the 1st phase at a length of 0.5λmax there will be a delay of the wave until its energy is completely accumulated at the boundary of the media (otherwise the photon wave will cease to be the previous wave) with a complete damping of its speed to 0.
- Zero speed leads to a dump-compression into a quantum dot of a spherical wave of a photon of radius λ_{max} with the speed of light c in time t_{max} (12), which is the delay time of the process.
- The compression of a radial wave over time t_{max} creates acceleration a_{max} (14), which is the source of forces (15) and energies (16) for subsequent transformation processes, in which the initial energy of the wave (8), as a result of its deceleration, is transformed, within the framework of law (9), into energy mass m_E (10):

$$a_{\max} = \frac{c}{t_{\max}}\left(\frac{m}{s^2}\right). \qquad (14)$$

$$F = m_E a_{\max}\,(N). \qquad (15)$$

$$E = m_E a_{\max} \lambda_{\max}\,(J). \qquad (16)$$

- In the 2nd phase of re-emission, due to the energy created by the acceleration $a_{max,}$ the compressed photon will accelerate from the speed 0 to the speed of light c with a relativistic increase in its size to a spherical wave of radius $2_{\lambda max}$ (Fig. 4). This process will create an average speed c/2 on the path $\lambda_{max}/2$, which will lead to an additional delay in their flight time by the value Δt (17):

$$\Delta t = \frac{\frac{1}{2}\lambda_{\max}}{\frac{1}{2}c} = \frac{\lambda_{\max}}{c}(s). \qquad (17)$$

In the range of light waves (0.380…0.760) $\times 10^{-6}$ m this delay will be the time (18):

$$\Delta t_{(380...760)} = \frac{\frac{1}{2}(0.380...0.760)\times 10^{-6}\,(m)}{\frac{1}{2}0.299792458\times 10^{9}\left(m/s\right)} = (1.257...2.535)\times 10^{-15}\,(s). \qquad (18)$$

The delay increases the period of the first radiation wave by 1.5 times (19), while the remaining waves and their periods remain unchanged:

$$\Delta t' = \Delta t + \frac{\frac{1}{2}\lambda_{\max}}{c} = (1.257...2.535)\times 10^{-15}\,(s) + \frac{\frac{1}{2}(0.380...0.760)\times 10^{-6}\,(m)}{0.299792458\times 10^{9}\left(m/s\right)} =$$

$$= 1.5(1.257...2.535)\times 10^{-15}\,(s) \qquad (19)$$

- The total time delay of the transformations will be equal to 2 periods t_{max} of wave radiation: at the 1st stage – compression, at the 2nd – acceleration (20), which corresponds to all the principles of the reality of physical actions according to the proposed model and hypothesis:

$$\Sigma\Delta t = 2t_{\max} = (2.535...5.570)\times 10^{-15}\,(s). \qquad (20)$$

The facts of the time delay of radiation from distant stars are known from astronomical observations. However, research is still needed to reconcile them with the results of (20). Then the photon, as an electromagnetic wave, continues its movement at a speed of c/n, where n is the index of the optical density of the medium of their propagation, which can be indirectly confirmed by the known scheme of refraction of light rays in a prism and in other optical media.

Since within the density of the intergalactic, interstellar and interplanetary vacuum the real number of physical particles for the re-emission of photons on their way must be incredibly large, however, on the contrary, there are at least 20 billion photons per nucleon [1,40]. Therefore, this process cannot be considered dominant over the ballistic motion of photons. For physical fields and intergalactic, interstellar and interplanetary plasma, there are also not enough zones with boundaries of different densities to fully ensure the process of re-emission of photons. This is confirmed by Dmitry Tipikin [41, p. 1065(2)], that the number of photon encounters with such areas and their boundaries is about 1000 on their way in 10 billion years. But at the same time, the direction of flight of re-emitted photons is unclear, which leads to the dispersion of light from distant stars and galaxies, which is not observed in real astronomical observations. The presented data again confirm the significant predominance of ballistic photons over re-emitted ones. In addition, for a ballistic flight due to the

acceleration energy a_{max}, it is sufficient to have only a vacuum and the space of the Universe created by it, without the physical fields and plasma required for re-radiation, the creation of which requires its own additional energy, which has not been found in the Universe.

It should be taken into account that stages of hypothesis 1–7 can be applied to the process of light refraction at the boundaries of optically transparent media, but their solution is also a separate problem that goes beyond the proof of the ballistic nature of photons, which is solved in this work.

All the above processes for proving the ballistic motion of photons as electromagnetic waves and physical particles do not contradict the real laws of physics, so they can be considered proven. However, the real identification of the quantum structure of photons and their pulses shown in Figure 5 requires the experiment proposed in [28,42]. Its new difference is that in order to obtain single photons, a rotating disk with micro-holes equal to the size of the transverse wave of a photon $2_{\lambda max}$ is introduced into the laser beam zone. In this case, the radius and rotation frequency of the disk are selected such as to cut off other photons emitted by the radiation source for the duration of the measurement.

The purpose of the measurement in this experiment is to identify the active wave zone and the empty zone preceding it over a length of $0.5\lambda_{max}$. For this purpose, the shift device 4 performs micro-movements of the target 3 with the radiation receiver on it, along the path of the wave of single photons from the light source 2 (Figure 8).

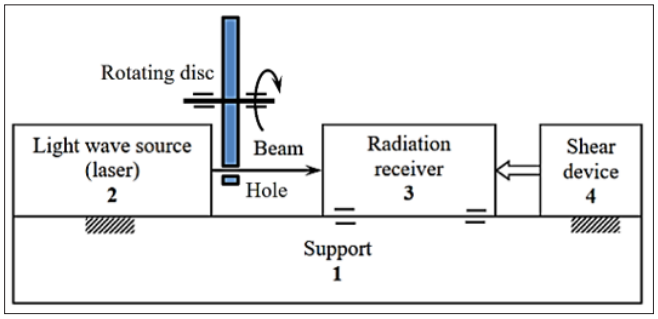

Figure 8: Diagram of the Device for Measuring the Path of Motion of Single Light Photons with the Possibility of Changing the Distance from the Source to the Radiation Receiver [42].

Conducting this experiment will clearly confirm or refute the form of the ballistic photon waves and the scheme of its motion proposed in Figure 5. All laboratories in the world and researchers with such technical and economic capabilities are invited to implement this experiment. Conducting measurements that are at the level of scientific discovery raises the achievements of these laboratories and their staff to world significance.

The results obtained in this work have all the attributes of a scientific discovery, but recognition of it as such is possible only after experiments have been conducted [43].

Conclusion

- It is proposed to consider photons as electromagnetic waves of the visible spectrum of radiation with a length of $(0.380…0.760) \times 10^{-6}$ m, and other pulses and wavelengths should be considered quanta of electromagnetic radiation, which will eliminate the ambiguity in understanding the processes associated with them.
- Photons are dual matter-wave physical objects in which the properties of an electromagnetic wave prevail when they move at the speed of light, and the properties of a material particle manifest themselves when they slow down or meet an obstacle.
- Ballistic photons, within the framework of the principle of dualism of the material world, are: radiation of electromagnetic waves moving radially from the source of their radiation at the speed of light c, and physical particles of matter that are formed during the braking and stopping of these waves at the moment of their encounter with an obstacle.
- From the moment of emission until the moment of absorption or re-emission, all photons are ballistic, their share in relation to non-ballistic photons is many times dominant.
- When moving, photons are transformed into spherical Planck waves of thickness 4.05×10-35 m, with a transverse surface of the sphere of 1 steradian, the radius of which and half the length of its arc are equal to the wavelength of radiation λmax.
- Spherical waves of a photon rotate perpendicular to the vector of their motion, and when reflected from the mirror surface of the sphere they turn inside out, maintaining the previous direction of rotation, therefore, a mirror change in the vector of the direction of their motion makes them antiphotons, in which the spin and direction of the right and left mapping change. This definition is correct, since the photon has no charge, like other physical particles-antiparticles.
- With a spherical wave of a photon, the parameters of which are larger than the size of the physical particles used for their re-emission, the process is reduced to the scattering or bending of particles by this wave, followed by the merging of the wave after going around an obstacle, which leads to the creation of an antiphoton.
- The evidence base for the proposed structure of ballistic photons and the processes of their movement is: a) the transition to the quantum principle of wave emission, b) the fulfillment of the principle of least action, c) the absence of contradictions with the real laws of the material world.

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Conflict of Interest: This work was carried out by the author alone, on his own initiative, on the basis of personal scientific works: [4,6,9,26,28,31,33,42]. It uses literature sources from open databases, so permission for their publication is not required.

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