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Ballistic Photons, Justification of their Structure and Movement Patterns

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ABSTRACT

Aim: The work relates to the fundamentals of quantum physics and photonics, in particular to the formation of photons in two states: elementary particles and electromagnetic radiation, and the parameters of their structure and motion processes. The study of these problems is a relevant and important task, has not been fully studied. In general case, a photon is considered an elementary particle and wave, quantum of energy emitted by its electromagnetic field, which does not exist without moving at the speed of light. However, the presence of the material part of a photon is not always manifested, so a photon is considered a wave of electromagnetic radiation and the photon has no internal structure and dimensions, except for its wave parameters. The process of photon movement is also problematic. It is believed that it exists as a particle at the moment of its origin, and then it is only the movement of a wave, which, when meeting a target, again turns into an elementary particle. Moreover, ballistic photons is not, and their flight occurs by absorption and re-emission of waves by the environment. However, all these factors have contradictions, the elimination of which is the **main goal** of the work performed. Its **scientific novelty** is a new justification for the presence and parameters of a ballistic photon and the processes of its movement on the basis of reliable laws of physics.

Methodology: The research methodology is based on the general principles of scientific knowledge, on the application of the laws of dialectics and reliable laws of physics. The author's method was also used – this access to the initial level of the material world, which is formed by physical fields and particles on the basis of natural physical constants: the speed of light c, Planck's constant h, gravitational constant G.

New Results of the Work: The possibility of the existence of ballistic photons in the dual form of substance and electromagnetic waves is shown, within the framework of the general physical principles of the existence of elementary particles and the real principles of their movement in the material world. It was found that the disappearance of ballistic photons in flight after their birth and their appearance when meeting a target can be explained by their quantum structure and the process of their movement by quantum jumps based on the Heseisenberg uncertainty principle.

Conclusions: The presence of the proposed quantum structure of the photon and the process of its movement is ensured by the absence of contradictions with the real laws of the material world that have a strict physical basis. For to confirm the reality of the existence of ballistic photons in the form of a real quantum mechanical particle, having the shape of a regular hexagon with a side of $^1/_6$ of the wavelength λ of their radiation, as well as their movement in quantum jumps at $^1/_6$ of the length of this wave, an experiment has been proposed. All laboratories with metrological equipment are invited to conduct the experiment.

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Introduction

The work relates to the fundamentals of quantum physics and photonics, in particular to the formation of photons in two states: elementary particles and electromagnetic radiation, as well as to the parameters of their structure and motion processes. The study of these problems is a relevant and important task, which has not been fully studied.

In the original interpretation of the photon, made in Einstein's work on the study of the photoelectric effect in 1905, it is a quantum of energy of electromagnetic radiation [1]. The name "photon" was given to these quantum particles by G. N. Lewis in 1926 [2]. In the "classical" interpretation, a photon is an elementary particle and a wave, or a quantum of energy emitted by its electromagnetic field, which does not exist without moving at the speed of light [3]. At this time, the photon is recognized as the only real elementary particle in the material world that does not have mass [3]. Hypothetical gluons are also considered massless elementary particles, but they are an intermediate product of the interaction of physical particles and fields, which brings them into the group of internal physical states of objects of the material world that do not exist in a free form [4].

However, the masslessness of the photon is an exception to the real general rules and principles of the formation of the material world and physical particles [5]. It should be taken into account

that exceptions to the general rules in the material world exist, but they relate to special cases of its formation under special conditions, the actual proportion of which is small, and photons are the most common particles in the Universe. In this case, it is believed that the photon has no internal structure and dimensions, except for its wave parameters [6].

Analysis of the State of the Problem, Selection of Goals and Objectives of Research

Photons, as quanta of electromagnetic waves and energy, include a wide range of wave energy radiation, with a wavelength λ from l_{min}, determined by dependence (1) through natural physical constants: the speed of light in a vacuum c, the Planck constant h and the gravitational constant G [7], up to $l_{min} = c = 0.299792458\ 10^9$ m [8],, in the frequency range of their radiation from $v_{min} = 1$ Hz [8],, determined from the dependence $v = \lambda/c$, up to v_{max}, determined from dependence (2) [7], (Figure 1).

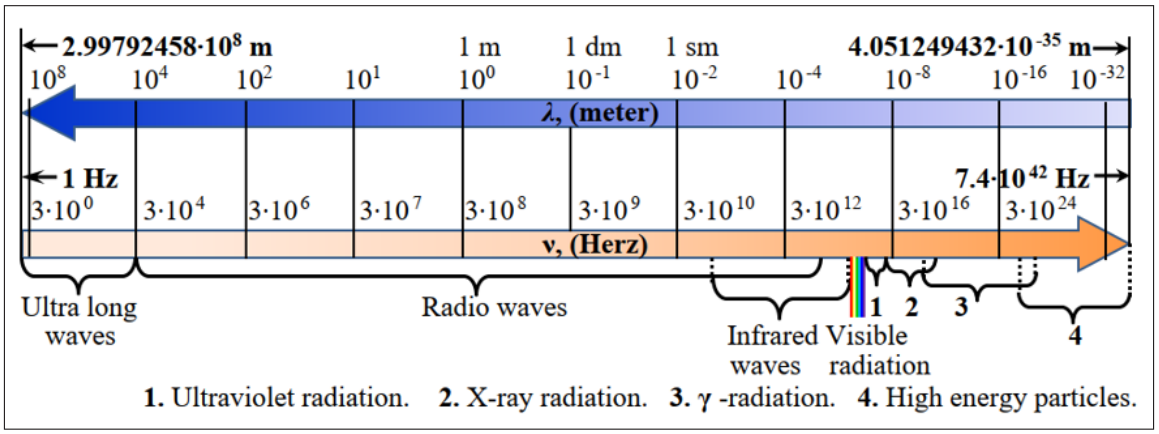

Figure 1: Full spectrum of vibration frequencies and wavelengths of electromagnetic fields [8]

Planck length $l_p = l_{min}$ (1), as the minimum possible value of wavelengths [7]

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

Punk frequency $v_p = v_G$, (2), as the maximum possible frequency value [7]

$$v_G = \sqrt{\frac{c^5}{Gh}} = \sqrt{\frac{\left[0.299792458\cdot10^{9}\left(\frac{m}{s}\right)\right]^5}{6.67430^{-11}\left(\frac{m^3}{kg\cdot s^2}\right)\cdot 6.62607015\cdot10^{-34}\left(\frac{kg\cdot m^2}{s}\right)}} =$$

$$= 7.39982\cdot10^{42}\left(s^{-1}\right) \rightarrow 7.4\cdot10^{42}\left(s^{-1}\right). \quad (2)$$

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

h – Planck's constant [9]

$$h = 6.62607015\cdot10^{-34}\,(\text{exactly})\,J\cdot s = 6.62607015\cdot10^{-34}\,(\text{exactly})\frac{kg\cdot m^2}{s},$$

G - gravitational constant [9]

$$G = 6.67430(15)\cdot10^{-11}\frac{m^3}{kgs^2}.$$

In addition, photons are also associated with a number of internal states of objects in the material world, which arise during various physical interactions, where the photon is an intermediary [10]. It should be taken into account that one article cannot provide answers to all problematic questions related to photons; this requires a very large amount of research. Therefore, in the work being performed, the internal states of photons are not considered in detail. Research is limited to ballistic photons, which are formed and live-in space-time freely and autonomously, and the wavelength range is limited to the zone of visible light and adjacent infrared radiation.

Ballistic photons include photons that move in a straight line before and after they are deflected while passing through the boundaries of other media. In addition to ballistic ones, there are scattered photons, which are formed in the form of 4 main variants of spheres [3]

- Spheres of a conical beam of ballistic photons expanding in all directions from one radiation source
- Spherical wave fronts of Schrödinger
- Annular layers obtained when a photon passes through a calibration hole (diffraction)
- Superposition of spherical waves when they pass through calibration slits (interference).

Since in all these cases the surface of the spheres of light radiation increases, its intensity drops sharply, so only ballistic photons of the direct path of motion actually reach us from distant stars. Ballistic photons are not observed simultaneously with scattered ones [11]. Spherical and concentric photon fluxes are not observed at large distances, so they are not considered in this work.

If until the middle of the 20th century, photons of light were depicted as a wave and an associated spherical particle-ball, then at present, in order to completely exclude even the fundamental possibility of photons having particles, they are represented only as an electromagnetic wave, without particle-balls [3].

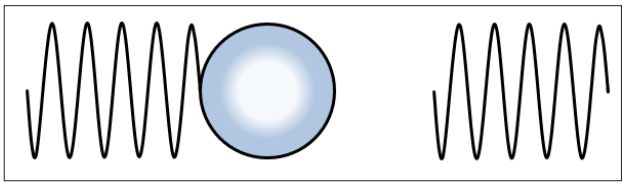

Figure 2: Traditional images of the photon as a wave and an elementary particle [3].

A wave, in its general understanding, is considered to be the physical state of matter observed actually or by instruments, with its sinusoidal changes in space-time. It is generally accepted that for light waves this state is created by their electromagnetic field [3].

However, it is impossible to completely reject the photon as a physical particle, which is confirmed by Professor Lebedev's experiments on identifying the pressure of light, the phenomenon of the photoelectric effect and a number of other experiments [12,13]. Therefore, replacing a photon with only a wave contradicts the general principles of the formation of the material world, in which physical particles simultaneously represent substance and a field. According to these rules and principles, the photon, as a quantum particle, is characterized by wave-particle duality and simultaneously exhibits the properties of both waves and particles [3].

In new theories, within the framework of wave-corpuscle dualism of light radiation, the photon as a particle is not ignored. However, it is believed that a wave arises when a photon moves, and as a particle it exists only when it is emitted and absorbed [14]. "A photon appears on the bus windows and then disappears, turning into a wave of radiation" [14]. This method of "separation" of a photon contradicts not only the general principles of the formation of objects of the material world, in which physical particles simultaneously represent both matter and a field, but also the condition of conservation of energy (at the moment of instantaneous disappearance of the photon, it must also go somewhere, and at the moment of its appearance - to appear from somewhere). Thus, in addition to the above problems of observing the principles of dualism, problems also arise in the modern representation of the parameters of the structure of photons and the process of their movement.

With the abandonment of ballistic photons, the problems of its movement are increasing, including this hypothesis about the movement of photons by re-emission of waves, since re-emission requires the presence of a medium and leads to the loss of time and energy to reproduce such processes [15]. Therefore, the movement of photons by transferring their energy is possible only in media with a dense concentration of their atoms (for example, in glass prisms), or in physical fields with a high concentration of energy. Such a concentration of atoms and energies is extremely rare in the space of the Universe, but light from distant stars and galaxies still reaches observers on Earth. In addition, the re-emission of photon waves by atoms does not guarantee that the new wave will continue its path in the direction of the original motion of the photon.

The solution to these problems is the main goal of the work being performed, and the justification of the parameters and structure of the photon on the basis of strict physical laws is its scientific novelty.

Research Methods

The work performed has the level of scientific discovery, for which there are still no rigorous search methods for finding them [16]. Therefore, in the work performed, general methods and principles of scientific knowledge were used - deduction and induction, based on the application of the laws of dialectics, as well as reliable laws of physics and general ways of developing scientific knowledge [3, 17-19]. We also used the author's method of transition to the initial level of the material world, which is formed by known physical fields and particles based on natural physical constants: the speed of light c, Planck's constant h, gravitational constant G, electric ε_0 and magnetic permeability μ_0, and Boltzmann's constant k_B, which is justified in [20, 21]. On their basis, all mechanical, electromagnetic, thermophysical and lighting quantities known in the material world were found [22-25], which confirms the significance and effectiveness of this method.

New Results and their Discussion

The analysis shows that the problems of photon dualism are also associated with the new concept of rejecting the presence of ballistic photons and their real absence before interaction with the target or means of measuring them [26]. Moreover, as a particle, it exists only when it is emitted and absorbed. However, it should be taken into account that a photon, like any material physical particle, is also a wave structure that is formed in space-time in the form of a closed bunch of electromagnetic and gravitational waves. In this case, the photon and other physical particles simultaneously

represent substance and field. Considering that in the presence of a massless photon, gravitational fields and waves can be excluded, therefore the source of energy Ev of the photon is waves of the electromagnetic field within the framework of M. Planck's energy law (3), the value of which depends on the period $t = 1/\nu$ of wave oscillation [3, 27]

$$E_\nu = h/t. \quad (3)$$

The process of photon emission can be carried out due to the external and internal energy of atoms. When heated from external sources, this energy arises inside the orbits of atoms due to the excitation and increase in the vibration frequency of their electrons, leading to the formation of photons, and when the photon confinement energy in the atom is exceeded, it is transferred to neighboring atoms until the photon leaves their common volume. It is further believed that this energy is transmitted by the waves of released photons and manifests itself at the moment of their meeting with the target, which is recorded experimentally. Thus, there is real photon energy, which does not disappear at the entire stage from its birth to hitting the target, which corresponds to the principles of the law of conservation of energy [3]. But if in [26] the photon is a real particle at the moment of birth and meeting the target, then it really exists along the entire path of its flight. This is confirmed by dust particles on the path of light rays, since they are present anywhere along their path, before the rays hit the target, or when the target itself moves towards the beam. If a photon particle disappears along the path of its flight, and then appears at the "right moment" and in the "right place" to meet the target, then there must be real physical laws and processes of such disappearance and its subsequent appearance [27].

However, a real explanation of all these processes must meet the criteria of the principle of least action, or Occam's razor [28]. In addition, the constant "knowledge" of the photon about the right time and place of such a meeting, which can be arbitrary, is a difficult to explain factor that has a level of "magic", and the recognition and dissemination of this hypothesis can be caused by the hypnosis of the importance of this scientific work. Such "magic" is possible only in abstract mathematics, the universality of which makes it possible to explain anything, depending on the level of mathematical training of the user. Although there are concepts that endow the photon with elements of "consciousness," one can hardly believe that the photon supposedly "notices," "experiences," or "sees" in those instants of time transformations that occur at the speed of light [29].

In addition, the existence of a photon only during the time period of its measurement, which can be different, is also "magical", and its appearance, at least a moment before measurement, automatically destroys this concept, since it means that the photon exists before its measurement. If the appearance of a photon occurs only at the moment the waves meet the target, then their transformation requires some time delay and real physical processes. Therefore, a separate study of such processes is required.

It is believed that the absence of a photon-particle was justified in experiments in which only spherical radiation waves were recorded. A critique of such work, carried out in [30] by Peter Jackson on pp. 1354-1355, showed that the authors of these measurements selected only those factors that supported their hypothesis.

It should also be taken into account that real process transformations are usually associated with energy losses. But if in this case this does not happen with a photon, then the process occurs at the quantum mechanical level, an example of which is the quantum mechanical principles of energy conversion at the levels of electrons in an atom [3].

On this basis, we can put forward a hypothesis that the laws of quantum mechanics operate in the flight of a photon, and the process of movement itself is quantum mechanical. The quantum basis of the photon itself, as indivisible portions of energy, is recognized in classical and modern scientific literature [3,31].

Theoretical Justification of the New Form of the Photon and the Pattern of its Movement

Within the framework of quantization principles, a new quantum structure of the photon was substantiated in [32]. At the same time, the ball, as a figure with a smooth measurement of parameters (which does not meet the quantization criteria, according to which changes are possible in quantum leaps) was replaced by a cube, and then by a regular trihedral prism - a figure with a minimum number of signs. These elementary quantum structures are further combined in a group of 6 pieces and form a regular hexagonal prism. In this case, a system is created of 3 real quarks, located evenly to each other at an angle of 2/3π, with a common central face and of 3 virtual quarks in the empty space between them (Figure 3) [8, 32].

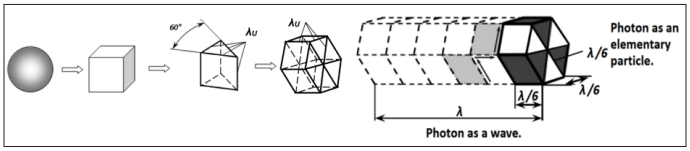

Figure 3: Scheme of the formation of the quantum structure of a photon (further research is necessary)

Real and virtual quarks flow into each other without losing energy, because the energy expended by a real quark to fill a virtual quark is completely returned at the next quantum phase of this process by a quantum leap, which creates virtual rotation for the quarks without energy expenditure and ensures the stability of the photon during movement and its "eternal" life [8].

On this basis, the full wavelength of the photon λ is formed in 6 quantum steps of rotation and translational motion of the energy of its quarks, and the photon, as an elementary particle, has the shape of a regular hexagonal prism, in which the dimensions of all its constituent elements are 6 times smaller than the wavelength (Figure 3). The photon diameter is 1/3 of the wavelength, the relationship $\lambda = 3D$ is confirmed experimentally [3]. In the circular direction of motion (along the perimeter of the hexagon), a full wave λ is formed from 6 quantum faces of the prism. It determines the energy state of the photon, since in each of the 6 positions of quantum jumps its total energy $E = hc/\lambda$ is located, and the entire wave is virtual and is formed by quantum jumps 1/6 λ. In this zone, the Heisenberg uncertainty principle operates and the photon "appears" only at the end of the jump within the time limits (4) [7]. The photon can rotate clockwise or counterclockwise, which is confirmed by its spin ±1 [3].

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

The movement of a photon is determined by the energy of its exit from atoms at the speed of light *c*. Having received an excess impulse of output energy, the ballistic photon makes a quantum leap from the atom by $^1/_6$ of its wavelength and then begins free flight with the same quantum leaps, which continue within the inertia of its movement until it encounters an obstacle (target). Thus, there are no fundamental contradictions for the formation and movement of ballistic photons, which indicates the real possibility of their existence.

The anisotropic shape of the hexagonal prism indicates the possibility of two options for its orientation, which is typical for the polarization of light (Figure 4) [8].

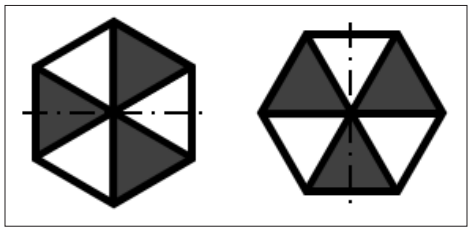

Figure 4: Change in photon orientation during polarization [8]

Anisotropy, as a possibility of photon polarization, serves as additional evidence of the correctness of the proposed model. However, for its implementation, an external influence is necessary to ensure the conditions for the occurrence of polarization, which corresponds to real processes.

The main characteristic of waves is a sinusoid [3]. However, a photon, like a wave, does not have a classical sinusoid, the smooth shape of which contradicts the principles of quantization. In addition, the sinusoid is virtual, since it is formed during the virtual rotation of quarks in a photon by quantum jumps (Figure 5) [8].

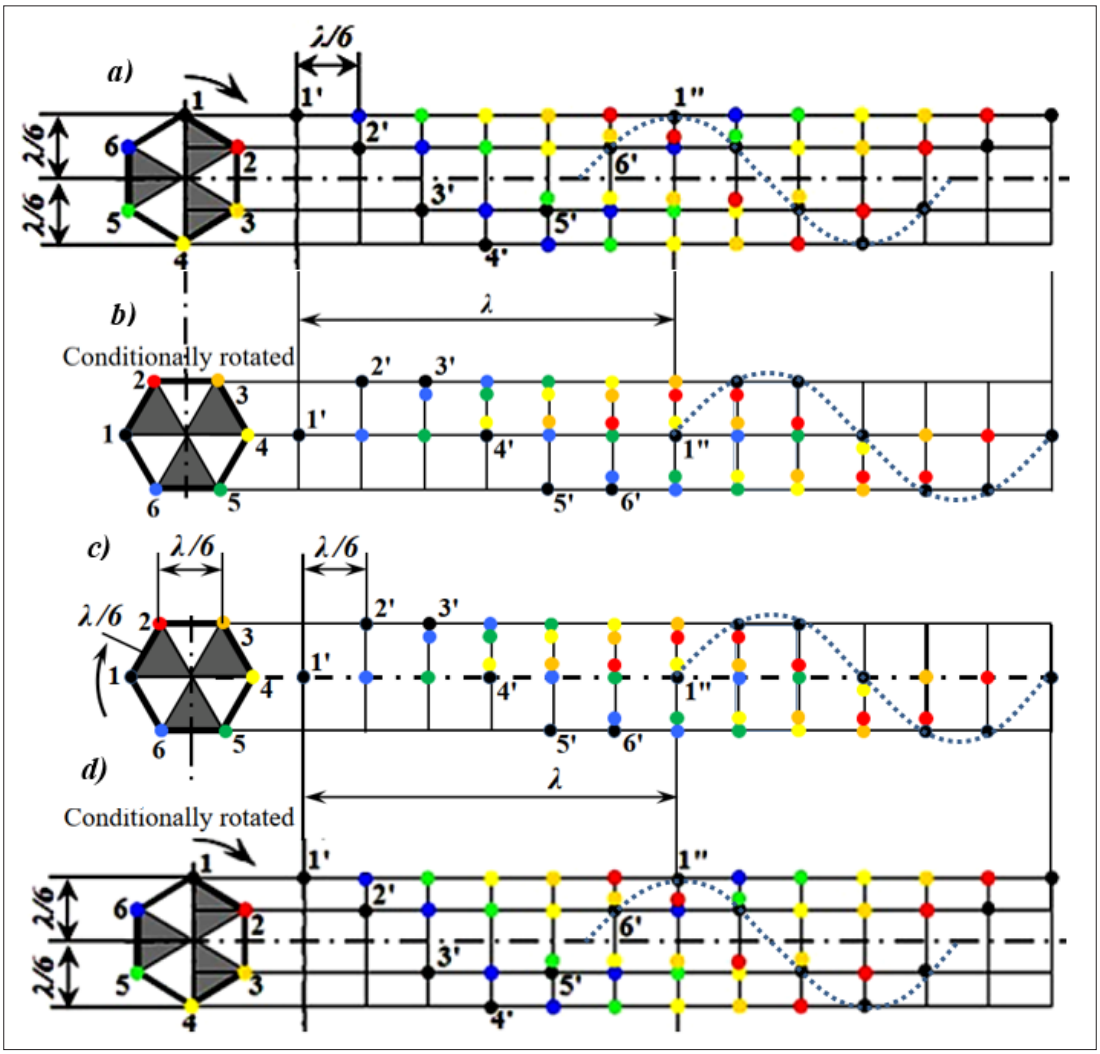

Figure 5: Formation of a scheme of motion and waves of a photon in the longitudinal
(a) and planes perpendicular to it, (b) as well as polarized photon in the longitudinal (c) and planes perpendicular to it (d) [8]..

In the longitudinal direction of the wave, point 1 of the beginning of the virtual rotation of quarks occupies the upper position 1', and then in quantum jumps moves down and forward by an amount $^1/_6$ λ in positions 2', 3', 4', and then similarly moves up and forward in positions 5 ', 6', 1'', forming a virtual sinusoid (Fig. 3.a) [8]. In the direction perpendicular to the longitudinal plane of the wave, a similar formation of a virtual sine wave occurs from the initial point of 1 quark – in positions 1', 2', 3', 4', 5', 6', 1'. But their quantum amplitude is less than that of the original longitudinal plane (Fig. 3.b) [8]. However, the smooth representation of the sinusoid (·····) formed by these quantum dots (which is recorded by instrument readings at the macro level) has the same amplitude for both directions of wave polarization [8]. This corresponds to modern ideas about light waves and confirms the correctness of the scientific positions put forward.

There are 6 such sinusoids, shifted relative to each other by phase $^1/_6$ λ. They form a virtual tube, which can be considered as a beam of photons or a beam of light. The color of the points in the figure is not related to the photon spectrum, but is adopted in order to distinguish sinusoids from each other. The position of a point on top is its conditional overlap of another point, which does not exist in reality, since all points are actually separated in space and time during quantum leaps [8].

The diagrams shown in Figures 4 and 5 are typical for the formation and movement of a ballistic photon.

The analysis carried out allows us to conclude that the unmanifested state of the photon at the moment of the quantum leap, within the framework of the Heisenberg uncertainty principle, corresponds to modern ideas about the absence of a photon at the moment of movement, and also simplifies the process of its disappearance and appearance along the route and when it hits the target. This justifies its absence in the measurements taken, but the photon exists throughout its flight. The automatic mode of disappearance and manifestation of a photon without loss of time and energy is a clear confirmation of its quantum-mechanical level and the correctness of the hypothesis put forward.

However, these theoretical conclusions require experimental confirmation.

Experimental Confirmation of the New Photon Shape and Pattern of its Motion

The task of this experiment is to detect the presence of a substance fraction of photons and their movement by quantum jumps of $^1/_6$ of the length λ of the photon wave. For this, it is necessary to create a method and a device capable of visually demonstrating the appearance of photons every $^1/_6$ of the wavelength λ of light.

The standard interferometer for measuring the length of the meter standard (Fig. 6), which is available in almost all metrological laboratories, can be used as a base. However, it is not suitable for measuring quantum wavelengths in steps of $^1/_6$ of the wavelength λ of the emitted light when irradiating the target – the receiver of these waves, which requires its modification.

Figure 6: Modern laser interferometer for measuring the metric quantities [33].

Creation of the proposed method is possible by using a source of stable light radiation with a given wavelength λ and a target as the surface of the final receiver for fixing this radiation. Such a light source can be a He-Ne/J2 laser, which forms the radiation spectrum of ultrashort (femtosecond) pulses [34]. On this basis, an application was submitted for the invention of a method for measuring photon jumps [35].

At the same time, the source and/or target - the receiver of light radiation is connected to a device capable of changing the distance between them by adjusting their relative shift with a step size of $^1/_6$ of the wavelength λ of light, while the target – the receiver of this radiation is able to register its energy, or the power of radiation. In this way, the detection of the full energy of photons $E = h/t$ is ensured in each movement of the target relative to the radiation source at a step of $^1/_6$ of the photon wavelength λ, while in the classical version it is the value $E = h/t$ only at the full wavelength λ. This testifies to the movement of photons by quantum jumps of length $^1/_6$ λ and to the presence of a particle of substance of photon, which has full energy $E = h/t$ and exists in each of these quantum jumps. Limiting laser light emission with a time pulse of $0.|185|\cdot10^{-14}$ s creates conditions for the formation of 1 photon with a wavelength of λ_{555} = 555 nm, which fully meets the requirements of the experiment [35]. However, to simplify the experimental base, it is possible to use red photons with a wavelength increased to 780 nm, as well as infrared waves that precede it.

Variants of this method include changing the distance by shifting it by a step of $^1/_6$ of the length λ of the light waves of the target-radiation receiver, or by shifting the radiation source by this step [35]. The essence and action of the method are shown in figure 7.

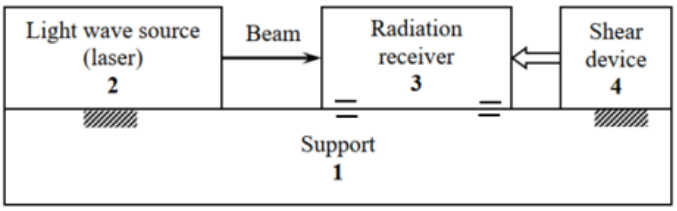

Figure 7: Schematic diagram of the device for measuring the passage of light with the possibility of changing the distance from the source to the radiation receiver [35].

A radiation source (laser) 2 is installed on the support 1, and a radiation receiver 3 (a target with photocells) is installed opposite it, which are able to fix the radiation energy. The target has the ability to shift by a distance of 1/6 of the wavelength λ of a particular photon with the help of a shift device 4. An additional shift of the target within the length of A radiation source $\lambda/6$ is carried out by the same device if it has the ability to move to a distance that is 2 or more times smaller than $\lambda/6$ [35].

Conducting the experiment finally establishes the structure and principle of photon movement. At the same time, there are no physical obstacles to the implementation of the proposed method, since there are no contradictions with the known laws of nature and physics. Everyone who has the organizational, technical and economic capabilities for this is invited to implement the method. For users who are the first in the world to conduct measurement data, there will be no patent usage fee. Conducting measurements that have the level of a scientific discovery [36] raise the indicators of achievements of laboratories and their staff to the world level.

Conclusion

- Ballistic photons exist in the dual form of substance and waves of their field, within the framework of the general physical principles of the existence of elementary particles and the real principles of their movement in the material world.
- Denying the existence of ballistic photons on the basis of known experiments is not correct, since their absence after their appearance contradicts the principles of conservation and transformation of energy and matter.
- The disappearance of ballistic photons in flight after their birth and their appearance when meeting a target can be explained by their quantum structure and the pattern of their movement within the framework of the general principles of Heseisenberg uncertainty.
- The possibility of the existence of the proposed structure of the photon and the process of its movement is ensured by the absence of contradictions with the real laws of the material world that have a strict physical basis and the implementation of the principle of least action.
- For to confirm the reality of the existence of ballistic photons in the form of a real quantum mechanical physical particle, having the shape of a regular hexagon with a side of $^1/_6\ \lambda$ of the wavelength of their radiation λ, as well as the process of their movement by quantum jumps at $^1/_6$ of the length of this wave, an experiment has been proposed.
- Final conclusions about the existence of ballistic photons can be made after experiments, which everyone is invited to conduct.

Gratitude

My thanks to Peter Jason, who persistently defended the traditional view that there are no ballistic photons. A dispute with him on the ResearchGate platform [29] led to the writing of this article.

Conflict of Interest: This work was carried out by the author alone, on his own initiative, on the basis of personal scientific works [8,16,20-25,27,31,35]. It uses literature sources from open databases, so permission for their publication is not required.

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