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Photon, A New Principle for Justification of Its Structure and Process of Motion

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Abstract

The work relates to the basics of quantum physics and photonics, in particular to the formation of photons in two states: as elementary particles and their electromagnetic radiation. The study of these problems is an urgent and important scientific task, which has not been fully resolved in terms of their structure and principle of action. In modern science, the photon is considered a fundamental elementary particle, which has neither its own structure nor dimensions, but only wave parameters. However, the denial of the material state of the photon contradicts the general conditions for the formation of the material world within the framework of the principles of dualism. Eliminating this shortcoming is the main goal of the work being performed. Its scientific novelty lies in the development of strict physical foundations for explaining the structure, parameters and process of photon motion. Working methods. The work was performed at the level of scientific discoveries for which reliable methods and techniques are not yet known, therefore, it used general methods and principles of scientific research, as well as the author's method of accessing the initial level of the material world.

Results of the work and their discussion. A new structure of the photon is substantiated, which includes not only its wave, but also a material particle. The substant particle of the photon is formed in the form of a regular hexagonal prism from 6 trihedral prisms, which are quarks, 3 of which are real quarks, and the empty space between them are virtual quarks. The transition of energy from real quarks to virtual ones, and then back, leads to virtual rotation of the photon, which ensures its stability, and the absence of losses in this process ensures the "eternity" of its life. A complete revolution of the quarks of the real part of the photon occurs in 6 quantum jumps, during which it moves translationally by the photon wavelength λ. When moving according to the proposed scheme, virtual sinusoids are formed, characteristic of the action of electromagnetic fields, which confirms the correctness of the proposed structure and scheme of photon movement.

Conclusion

The proposed structure and pattern of photon movement implements the principle of least action, which dominates in the material world. At the same time, there are no contradictions with the real laws of the material world, as well as the need for uncertain physical processes and energies for its implementation, which is the evidence base for the work.

Keywords: Photons, Their Structure and Process of Movement, Methods and Laws for Their Proof.

1. Introduction

The work relates to the basics of quantum physics and photonics, in particular, to the formation of photons in two states: 1) elementary particles, 2) electromagnetic radiation. The study of these problems is necessary for a better understanding of the fundamentals of the structure of the material world and the general development of scientific knowledge about the universe, which is an urgent and important task. The work of many scientists of the world, from ancient times to the present day, has been devoted to solving the problems of the nature of light and its radiation (light was defined by the term photon only in 1926 by the chemist Gilbert Lewis) [1, 2]. At the same time, the initial interpretations of the nature of light as corpuscles (Gassendi and Newton) gave way to the justification of its wave structure (Huygens, Fresnel, Maxwell) and were finally established within the framework of modern principles of dualism as a matter-field system (Louis de Broglie) - simultaneous states of photons as elementary physical particles and wave radiation.

1.1. Analysis of The State of The Problem and Formulation of Research Objectives

Despite the large number of scientific works in this field, all the

problems of determining photon parameters have not been fully resolved. First of all, its structure is not established, and modern science considers the photon as a fundamental elementary particle that has neither its own structure nor dimensions. In general, a photon is represented as a wave, and its physical particle is represented as a ball. At the same time, the dispute regarding the wave and substance characteristics of the photon continues at the present time. It is generally accepted [3] that a wave appears when a photon moves, and particles appear when a photon is emitted and absorbed. This approach is caused by the desire to abandon the photon as a physical particle, and replacing it only with a wave allows us to abandon its mass. There is also no clear justification of the real physical principles of the movement of the photon, as an elementary physical particle, there is only its connection with waves, in the form of observable physical fields with a sinusoidal space-time character. It is generally accepted that this type of light wave is created only by its electromagnetic field, which has no substance [1].

However, dividing a photon separately into a wave and a particle contradicts the general conditions for the formation of the material world within the framework of the principles of dualism, according to which physical particles simultaneously represent both matter and a field [1]. This is especially pronounced at the atomic and subatomic levels of natural objects, therefore the photon, as a physical object of the quantum level, is characterized by wave-particle duality; it is simultaneously a wave and a physical particle [1]. Currently, the photon is considered a massless physical particle - in all textbooks and reference books on physics, its gravitational mass is assumed to be 0. But this is the only massless particle in the material world, which is a surprising exception to the general rules of its formation and existence in the Universe [1]. For a long time, neutrinos claimed the same role, but at present their mass-energy indicators have been determined. Experimental estimates for May 2012, which were obtained in the work of the Australian WiggleZ collaboration at the Anglo-Australian telescope, set the upper limit of the energy mass for all neutrino flavors at the level of $Ev = 0.29$ eV [4]. At an energy of 1 eV = $1.602176634 \cdot 10^{-19}$ J, its wavelength will be value (1), which reduces it to a wavelength range close to ultraviolet light waves:

$$\lambda_\nu = \frac{hc}{E_\nu \cdot 1.602 \cdot 10^{-19}(J/eV)} = \frac{6.626 \cdot 10^{-34}(Js) \cdot 0.2998 \cdot 10^{9}(m/s)}{0.29\ (eV) \cdot 1.602 \cdot 10^{-19}(J/eV)} = 4.28 \cdot 10^{-6}(m). \quad (1)$$

where *c, h* are fundamental physical constants, the values of which are recommended CODATA [5]:

Speed of light in vacuum *c*: $c = 0.299792458 \cdot 10^{9}\ (\text{exactly})\frac{m}{s}$,

Planck constant *h*:

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

The lack of mass of a photon cannot be considered a strictly proven scientific truth in the presence of ego energy, because within the framework of the relationship between the energy E_γ and the mass m_γ of a photon according to Einstein's law (1), the energy without mass reduces to 0, which contradicts the real data on the energy of photons [1].

$$E_\gamma = m_\gamma c^2. \quad (2)$$

Therefore, the zero mass of a photon is only one of the axioms accepted in science.

The 2nd axiom - photons do not have a rest mass $m_{\gamma 0}$, because without moving at a speed υ_γ, which is equal to the speed of light *c*, they do not exist.

Today, these axioms are recognized by the majority of world scientists, including Einstein in the general theory of relativity (GR), in which gravity is replaced by the curvature of space, which made it possible to explain the deviation of light rays from massless photons when they pass near massive objects [6, 7]. However, there is no direct evidence of zero photon mass, there are only indirect ones: 1) it is $m = 0$ that allows the photon to move at the speed of light c under conditions of relativism of mass; 2) interference of light is excluded when it moves in the Universe over long distances; 3) violation of the Lorentz invariance principle is excluded.

These axioms and indirect evidence were challenged in [8]. based on the experiments of Professor Lebedev, who revealed the pressure of light within the pulse of photon motion energy (3), since it replaces taking into account mass [3,9]. Its value can be found from 2 laws for determining energy: the energy of waves E_λ of length λ according to de Broglie's law (3) and the rest energy of a body E_m of mass m according to Einstein's law (1), and the relationship between by them $E_\lambda = E_m$, which strictly applies to objects of the atomic and subatomic levels of the material world [1].

$$E_\lambda = \frac{hc}{\lambda}, \tag{3}$$

In this case, the momentum P_γ of motion of a photon having the speed of light c can be determined without taking into account its mass simply mathematically, within the framework of dependence (4):

$$P_\gamma = \frac{hc}{\lambda c} = \frac{h}{\lambda}(kgm/s). \tag{4}$$

However, this technique is a simple mathematical trick, since the physical meaning of the momentum is inextricably linked with the mass m_γ within the framework of the real dependence:

$$P_\gamma = m_\gamma c. \tag{5}$$

Thus, the exclusion of mass in the momentum of motion is not a correct action in real physics for the processes of motion of a photon and other particles.

A number of experiments were proposed to confirm the presence of photon mass, and the structure of the photon and the pattern of its movement as an elementary particle were also proposed [8]. However, their discussion on the ResearchGate platform led to disputes indicating the insufficient validity of the proposed structure and photon motion scheme [10].

Elimination of these shortcomings is the **main goal** of the work performed. Its **scientific novelty** is the development of strict physical foundations and principles for explaining the structure, parameters and process of photon motion.

1.2. Research Methods

The work performed has the level of scientific discovery, for the creation of which there are still no strict methods [11]. Therefore, it used general methods and principles of scientific research - deduction and induction, based on the application of the laws of dialectics, reliable laws of physics and general ways of developing the theory of knowledge [1, 12, 13]. The author's method of transition to the initial level of the material world, justified in [14–16], was also used.

2. New Results and Their Discussion.

For further research, the method was used [14-16], based on the transition to the initial quantum mechanical level of the material world, on which there is still nothing but the space of the Universe with the quantum parameters of the wavelength of its Unified Field: $\lambda_U = 4.05 \cdot 10^{-35}$ m , their time period $T_U = 0.135 \cdot 10^{-42}$ s, which are created by quantum energy $E_U = 4.9 \cdot 10^9$ J, in the form of numerical values real for the state of the Universe. Their physical meaning, within the framework of modern knowledge, reflects dependencies (6), (7), (8) for determining the Planck values of length l_P, time t_P and energy E_P [17]:

$$\lambda_U = l_p = \sqrt{\frac{hG}{c^3}} = \sqrt{\frac{6.62607015 \cdot 10^{-34}\left(\frac{kg \cdot m^2}{s}\right) \cdot 6.67430 \cdot 10^{-11}\left(\frac{m^3}{kg \cdot s^2}\right)}{\left[0.299792458 \cdot 10^9\left(\frac{m}{s}\right)\right]^3}} = 4.05125 \cdot 10^{-35}(m), \tag{6}$$

$$T_U = t_p = \sqrt{\frac{hG}{c^5}} = \sqrt{\frac{6.62607015 \cdot 10^{-34}\left(\frac{kg \cdot m^2}{s}\right) \cdot 6.67430 \cdot 10^{-11}\left(\frac{m^3}{kg \cdot s^2}\right)}{\left[0.299792458 \cdot 10^9\left(\frac{m}{s}\right)\right]^5}} = 0.135138 \cdot 10^{-42}(s), \tag{7}$$

$$E_U = E_P = \frac{h}{t_P} = \frac{6.62607015 \cdot 10^{-34}(Js)}{0.135135 \cdot 10^{-42}(s)} = 4.90317 \cdot 10^9(J) \tag{8}$$

where G – is gravitational constant [5]: $G = 6.67430(15) \cdot 10^{-11} \frac{m^3}{kgs^2}$.

Further, from these parameters in the material world, all fundamental physical constants are automatically formed, for example, the speed of light in vacuum $c = \lambda_U/T_U$, Planck's constant $h = E_U T_U$, etc. [18]. These constants are the basis of the material world and the individual characteristics of our Universe (its "last name", "first name", "second name", etc.). Since the fundamental physical constants are real physical quantities, their constituent initial quantities are also real: λ_U, T_U, E_U, which serves as an evidence base for the correctness of the selected parameters. Constants and the laws of their formation make it possible to obtain strict physical (rather than abstract mathematical) calculated dependencies for determining all known parameters in the Universe and its constituent quantities, with unambiguous final solutions in numerical form [19–22].

Confirmation of the real connection between fundamental physical constants and parameters and objects of the material world can be found in work, which shows that the constants h and G manifest themselves in the real parameters of liquids [23]. On this basis, the entire material world is further formed at all of its following levels: 1) elementary particles, 2) atomic nuclei (nucleons), 3) atoms, 4) molecules, etc.

The work took into account that, within the framework of wave dependencies (3), (4), physical objects can be classified as photons in the entire possible range of their wavelengths, from the minimum value λ_{min}, equal to the Planck length (6) to the maximum length λ_{max}, numerically equal to speed of light in 1

second (s), $\lambda_{max} = c \cdot 1(s) = 0.299792458 \cdot 10^9$ m, and the oscillation frequency ν of these waves varies from 1 Hz to $7.4 \cdot 10^{42}$ Hz (Fig. 1) [23, 24]:

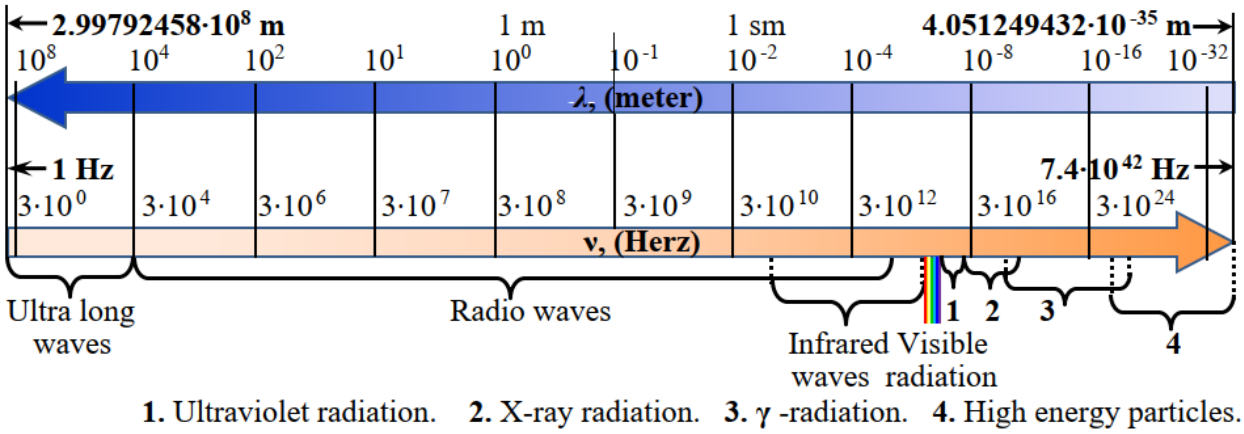

Figure 1: Full Scale of Wavelengths and Frequencies of Their Vibrations in The Material World.

This range of wavelengths and their frequencies was justified in [8, 24]. It should be taken into account that for this level of the material world (λ_U=4.05·10-35 m), there are neither measurement tools nor methods for their implementation, which puts special conditions on the search for an evidence base. However, it was taken into account that at the quantum level of the material world there are no other movements except quantum jumps along and across by an amount λ_U over the time period T_U, which follow from the physical laws, forces and energies that implement them. Therefore, the principle of minimal action, which arises and dominates in most all processes of the material world, was adopted as the evidence base (its simplest confirmations are the Pauli principle and other laws of the formation of atoms and molecules, including isotopes and isomers).

Within the framework of this principle, it was proven that the shape of the minimum quantum of space of the Universe is not a ball, but a volumetric physical object that changes in quantum jumps, of which the minimum number of signs is a trihedral prism [15, 16]. Next, 6 such prisms are grouped into a closed regular hexagonal prism, which consists of 3 sectors of real quarks, connected at angles of 2π/3 by their vertices and alternating with 3 sectors of virtual quarks between them [16]. Quarks reduce the original abstract trihedral prisms to real physical objects. A virtual quark is not an antiquark in its traditional interpretation; it is an empty space, adequate to the shape and size of the real quarks between which it is located.

The exchange of energies between real and virtual quarks occurs without loss, since the energy expended by the real quark to fill the virtual quark is then completely returned in the next quantum phase of this process, in which there are no obstacles or counteractions. This leads to virtual rotation of quarks and ensures high stability and "eternity" of life of the quanta of space of the Universe. The connection between the minimal quanta of space and gravitons and photons is substantiated [8, 16]. However, it has not been considered fully enough, since the main goal in [16]. was to substantiate the parameters of quanta of space, and in [8]- the presence of photon mass.

By analogy with the quantum of space of the Universe, a photon, as a physical particle, can be represented in the form of a hexagonal prism, similar to a quantum of space, but with its own real energy of the physical field $E = h/T$. The physical field in a closed volume represents substance. It also consists of 3 real and 3 virtual quarks, flowing into each other without loss of energy. Further, this action creates a virtual rotation of the photon without energy consumption and ensures its stability during movement and "eternal" life. Light in the general case is the front of the movement of a group of photons. The full wavelength of a photon λ is formed through 6 quantum jumps of rotation and translational motion of the energy of its quarks, as shown in Fig. 2 [8]:

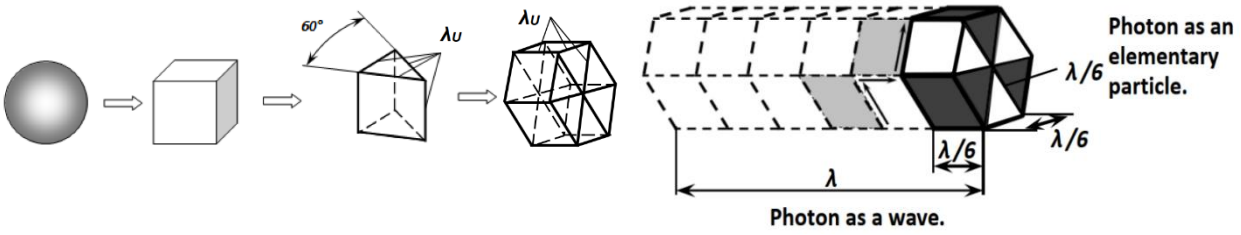

Figure 2: New concept of the formation and movement of photons (further research is necessary).

It is known that the structure of the proton and neutron is considered to be quark, but they are depicted in the form of balls, which contradicts the principles of quantization (Fig. 3) [26]. Therefore, it is necessary to eliminate this shortcoming.

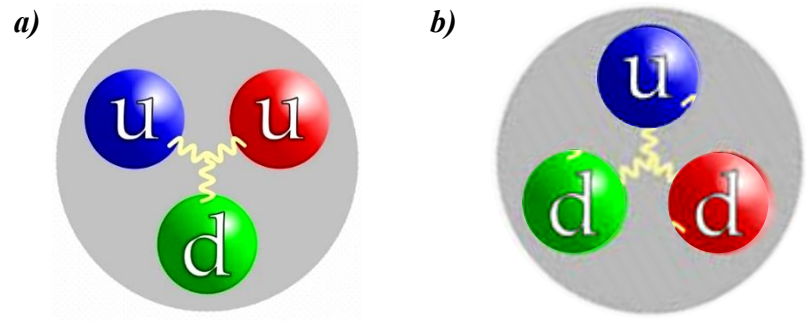

Figure 3: Quark structure of the proton (*a*) and neutron (*b*) [26]

Quarks never occur in isolation; they can only be found within: 1) hadrons, which include baryons (such as protons and neutrons) and mesons; 2) in quark-gluon plasma [26]. In this case, protons consist of two up (u) and one down (d) quarks (Fig. 3.a), and neutrons consist of one up (u) and two down (d) quarks (Fig. 3.b). Consequently, actually observed material matter may consist of similar quarks, in particular, these are physical particles of atomic nuclei and nucleons. This factor is the evidence base for the presence of quarks in photons.

The parameters of quarks in protons and neutrons have already been determined, and the quarks that make up the quanta of space of the Universe and photons still need to be determined and identified, but this goes beyond the scope of the scientific problems solved in this work. When moving, a photon has a wavelength λ, and as an elementary particle, it is a regular hexagonal prism, all of whose constituent dimensions are 6 times smaller than the wavelength [8]. The division of λ by 6 is justified not only by the quantum size relationship, but also by the connection with the circular Planck constant, which was obtained by Dirac as a result of dividing the Planck constant h by the number 2π: $\hbar = h/(2\pi)$ [27]. It is used to describe closed physical objects (for example, elementary particles) to which the photon belongs, but at the quantum mechanical level there is no fractional number π, only the integer numerical value 6 exists. Modeling of the photon shows that its real part (physical particle) in the direction of its movements are 6 times shorter and 3 times thinner than the photon wavelength [8]. But in the circular direction of motion (along the perimeter of the hexagon), a complete wave is formed, which determines the energy state of the photon $E = hc/\lambda$. In this case, the longitudinal wave λ is formed in 6 consecutive positions of the real part of the photon, but each of them contains its total length λ and its total energy E. However, such a wave is actually virtual, existing only when the photon moves [8].

The anisotropic shape of the hexagonal prism indicates the possibility of 2 options for its orientation, which is typical for the polarization of light (Fig. 4) and serves as additional evidence of the correctness of the proposed model. However, for its implementation, an external influence is necessary, which provides the conditions for the occurrence of polarization, which corresponds to real processes.

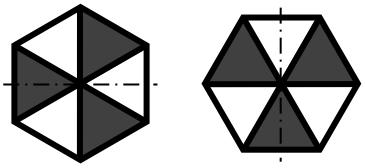

Figure 4: Change in photon orientation during polarization

The main characteristic of waves is a sinusoid [1]. However, a photon, like a wave, does not have a real sine wave, whose smooth shape contradicts the principles of quantization. It is virtual, since it is formed during the virtual rotation of quarks in a photon (Fig. 5) [8].

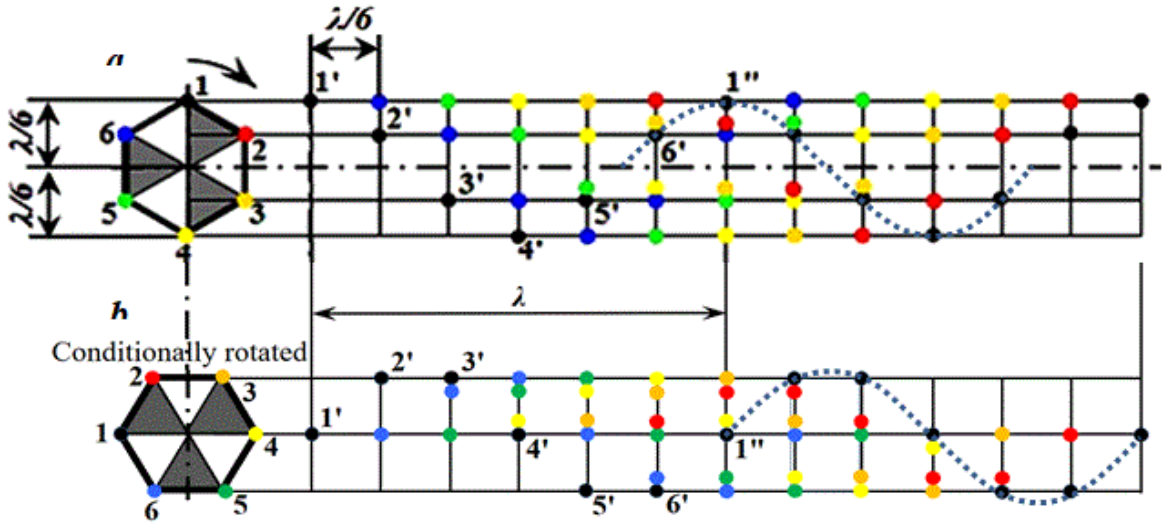

Figure 5: Formation of a scheme of motion and waves of a photon in the longitudinal (a) and planes perpendicular to it (b).

In the longitudinal direction of the wave, the starting point of 1 quark occupies the upper position 1', and then in quantum jumps moves down and forward by the amount λ/6 in positions 2', 3', 4', and then similarly moves up and forward in position 5 ', 6', 1", forming a virtual sinusoid (Fig. 5.a) [8]. In the direction perpendicular to the longitudinal plane of the wave, a similar formation of a virtual sinusoid occurs from the starting 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. 5.b).

There are 6 such sinusoids, shifted relative to each other by phase λ/6. They form a virtual tube, which can be considered as a photon beam or a beam of light [8]. The color of the dots 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 coverage of another point, which does not exist in reality, since they are actually separated in space and time during quantum leaps [8]. The sinusoid (·····), which at the macro level is formed by these quantum dots, has the same amplitude for both directions of wave polarization.

For polarized light, the formation of sinusoids has the opposite appearance in the longitudinal (Fig. 6.a) and perpendicular to it planes (Fig. 6.b), compared to that shown in Fig. 5.a, b, however, their phase parameters remain the same.

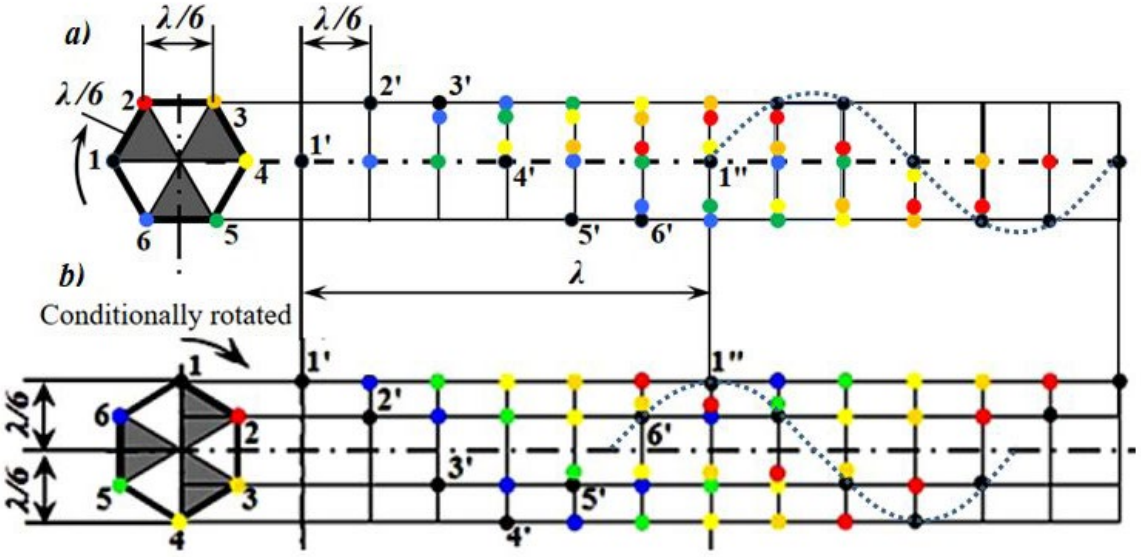

Figure 6: Formation of patterns of motion and waves of a polarized photon in the longitudinal (a) and planes perpendicular to it (b).

The formation of virtual sinusoids is another proof of the correctness of the proposed model of the photon and its movement. In addition, helicity, as the direction of rotation of quarks in this model, has a value of ±1, which is also additional confirmation of its correctness. The analysis carried out allows us to conclude that at the initial quantum level of the material world, within the framework of the principle of minimal actions, only such a variant of the formation of a photon and the pattern of its movement is possible, which is presented in this work. There are no other options even in principle; they simply do not

exist physically. It should be taken into account that photons with wavelengths in the visible spectrum of light differ from the original quantum quantities λ_U, which makes the use of the proposed evidence questionable. However, it was proven that a photon is a quantum physical quantity at any wavelength that *cannot* be further divided [8]. For example, a photon of red light with a wavelength of 760 μm cannot be divided into 2 photons

Another proof of the correctness of the proposed model of the photon and the scheme of its movement is their consistency with the known real laws of physics [1]. Only when physical contradictions are found in the proposed model will it become untenable. Until then, it is a scientific truth, which has been proven within the framework of the given evidence base and can be used in further research. In contrast to the concept, The photon, as a physical particle, exists not only at the moment of its birth and at the moment of its absorption and registration by instruments, but also along its entire path, which is confirmed by smoke or dust on the path of light rays. They only appear and are visible when colliding with an obstacle, but they are there even before the collision. This provision differs the new concept from that proposed in [3].

The length $\lambda/6$ is actually the length of carrier waves for all types of quantum radiation. To prove this, it is necessary to prepare and conduct experiments to study the wave structure of visible light, reaching wavelengths $\lambda/6$, which is proposed to be done in further work. They require registration of the arrival of photons at the target with their full energy, but with an incomplete wavelength by quantum jumps of length $\lambda/6$. The accuracy of modern instruments (standard meter) allows this to be done [5]. Everyone who has the technical capabilities is invited to conduct The experimental plan is available.

These factors can provide new information about physical particles, incl. about neutrinos.
It is more correct to measure the λ wave along its crests, rather than along the midline; these points are absent during quantum jumps [8]. However, at the micro and macro levels, the flat top of the sinusoid becomes blurry, which makes it difficult to accurately determine the peak of the phase point of the wave, and the center line of the sinusoid clearly records this position, so the traditional measurement option should be considered more appropriate.
2nd axiom - photons do not have a rest mass $m_{\gamma 0}$, because without movement at speed c, they do not exist, is also untenable, since there is no abstract "light" that moves at speed c, but there is the movement of real photons, which is slowed down by the medium of their movement. In interstellar and intergalactic space, this medium is the gravitational field of stellar systems, stars, planets and atoms (mainly hydrogen) distributed between them. Braking is also possible by the electromagnetic fields of these systems. But interstellar atoms are mostly neutral, and for stars, the electromagnetic field is created by emissions of their plasma, which are local, so for its impact, you need to get into such flows.

Since the fraction of such objects and their flows does not exceed 5% of the content of the Universe (within the total fraction of matter in it [28]), the corresponding deceleration of photons in outer space will not exceed this value and practically eliminates the interference of light from distant and nearby stars. This factor creates the Doppler effect, but the wave displacement in this case occurs at the level of atomic sizes. However, this process also goes beyond the scope of the work being performed.

The concept is also known, which replaces the movement of photons with the process of transferring their energy [3]. However, in this case, the photon must excite some space or field next to itself in order to transfer its energy to it (light is wave energy and it must go somewhere within the framework of the principle of conservation of energy) [1]. Such a space or field must be "tuned" to the specific field of the photon and the parameters of its wave (this stage is mandatory, since photons are different, but space and field are universal). This field must then transmit the wave's energy to a neighboring space or field, which must also repeat this adjustment process. Such processes cannot occur without the expense of time, so a delay in the movement of the photon is inevitable.

The higher the photon energy, the longer the restructuring takes place and the greater the decrease in photon speed, and "white" light during "transmission" would always be a spectral rainbow, which is not the case in reality. In a vacuum, such a process is not observed or recorded, since the speed of light in a vacuum is the standard c. It should be taken into account that the "transmission" process is possible at a high concentration of atoms, which occurs when light passes through a prism, where it is decomposed into a spectrum with different refractive indexes, depending on the energy and its of "assimilation" speed and its further transfer to the environment, for example - of the atoms. An example of dispersion is the decomposition of white light into a spectrum of 7 colors when it passes through a prism (Newton's experiment), shown in Fig. 7 [29].

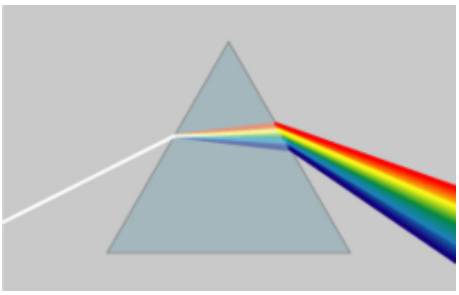

Figure 7: Decomposition of a white light beam into a spectrum as a result of its dispersion when passing through a prism (Newton's experiment) [29].

It is possible to create artificial environments and electromagnetic fields, where a significant (up to 10 thousand times) slowdown in the speed of photons occurs, which is a special case in the material world [30]. Since the transmission of photons without a "condensate" is possible, its existence is doubtful. The nature of the material world is not so wasteful that its "wastes" on it, what it does not need.

In fact, these are all areas of physical objects in which "transfer" of photons is possible. In other spheres they fly independently, without loss of energy (in the absence of collisions with atoms and physical particles and when they fall within the range of the fields of other physical objects). This again corresponds to the principle of minimal action that prevails in the material world. Consequently, in most cases, photons move according to the scheme proposed in this work.

The presence of a material part in a photon, which has a real gravitational mass and its quark structure, requires a revision of the general picture of the physical particles of the material world (Fig. 8) [8, 31]. The photon is not only an interaction, but also a real elementary particle.

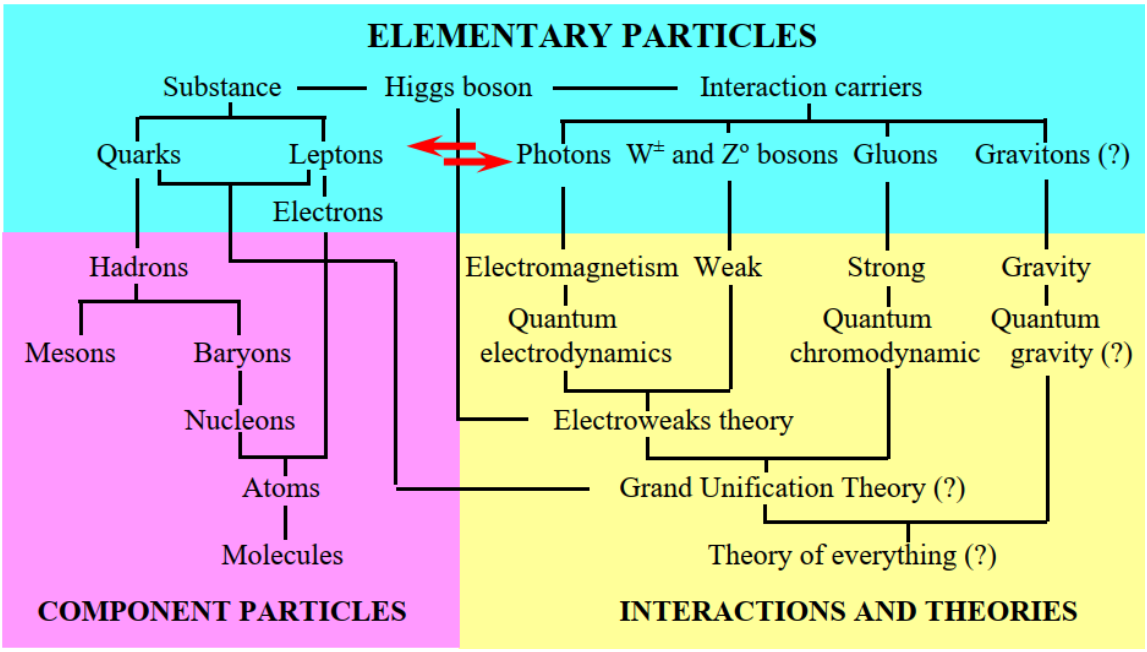

Figure 8: General structure of elementary particles and interactions in the material world [31].

Thus, the proposed work has the level of scientific discovery and opens up new broad opportunities for future research of the material world [32].

3. Conclusion

• The structure of the photon is proposed, which includes not only its wave, but also a real of substance particle.

• The substance part of the photon (particle), is formed in the form of a regular hexagonal prism from 6 regular trihedral prisms, which are quarks, 3 of which are connected by their vertices at an angle of 120° with 2π/3 and are real quarks, and the empty space between them are virtual quarks. Their totality forms the structure of the photon as an elementary particle.

• The transition of energy from real quarks to virtual ones, and then back, leads to virtual rotation of the photon, which ensures its stability, and the absence of losses in this process ensures the "eternity" of its life.

• A complete rotation of the quarks in the substance part of the photon occurs in 6 quantum jumps, as a result of which it moves translationally by the photon wavelength λ, which makes it possible to determine the dimensions of a real hexagonal prism in $\lambda/6$ along each of its faces. This combination of factors actually

shapes the process of motion of a photon as an elementary particle.

• In the process of photon movement according to the proposed scheme, virtual sinusoids are formed, characteristic of the action of electromagnetic fields, which well confirms its correctness.

• The evidentiary basis for the proposed structure and scheme of photon motion is the transition to the initial quantum level of the material world, on which there is nothing but quantum jumps along and across the movement. This excludes other photon motion and structure schemes other than those proposed in this work.

• The proposed structure and movement pattern ensure the implementation of the principle of least action, which dominates in the material world, which is the second (after virtual sinusoids) element of the evidence base.

• The third element of the evidence base is the absence of contradictions with the real laws of the material world and the exclusion of the need for uncertain (exotic) physical processes and energies for its implementation, such as "vortices", "condensate", "ether" and "dark energy", the parameters of which are not defined on a strict physical basis.

• The limiting values of wavelengths and frequencies of their oscillations that are possible in the material world have been determined, and the quantum structure of photons and other types of wave radiation has been substantiated over the entire possible range of these lengths and frequencies, which makes it possible to apply the proposed option for the formation of the structure and operating principle for them.

• It is shown that in the space of near and deep space the movement of photons by transferring their energy is impossible, due to the low concentration of physical fields and matter in them that can implement such a process, therefore their own flight occurs, in quantum leaps of 1/6 of the wavelength along and across the direction of its movement.

• The movement of photons by transferring their energy is possible only in media with a dense concentration of their atoms (for example, in prisms), or in physical fields with a high concentration of energy. Moreover, the higher the photon energy, the more time it takes to receive and transmit it, which slows down the speed of this process and leads to different angles of deflection of incoming waves.

• The presence of the material part of a photon introduces them not only into the sphere of physical interactions, but also into the sphere of physical particles, which requires a revision of the existing relationships between them in the material world.

Conflict of Interest

This work was carried out by the author alone, on his own initiative, on the basis of personal scientific works: [8, 11, 14 – 16, 18 – 22, 24, 25]. It uses literature sources from open databases, so permission for their publication is not required.

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