Two-rotor structure of the photon
Photon gyroscopic effect

Professor Vladimir Leonov

This article was published like chapter 6 in the Leonov's book: Quantum Energetics. Volume 1. Theory of Superunification. Cambridge International Science Publishing, 2010, pp. 421-511. The structure of a photon as a wave particle has long remained incomprehensible to us. Analysis of the Maxwell equations for the electromagnetic field in the vacuum indicates that the spherical wave cannot expand in the relativistic region. This allows us to represent the electromagnetic field of a photon in the form of two rotors: electric and magnetic. These rotors are located in orthogonal planes with the possibility of rotation of the polarization planes. This ensures the constancy of the speed of the photon with the speed of light. Now that we know the two-rotor structure of a photon, we can analyze photon-photons interactions. This is a very important fundamental knowledge that is needed for the development of new quantum technologies: quantum computers, quantum entanglement, quantum generators (lasers) and others.

After introducing in 1905 the radiation quantum referred to subsequently as the photon, Einstein is justifiably is regarded as one of the founders of quantum theory. However, Einstein could not accept the statistical nature of the wave function which is the basis of the calculation apparatus of modern quantum (wave) mechanics and in his final months assumed that the quantum theory should be deterministic. Only after discovery in 1996 of the space-time quantum (quanton) was it possible to develop a deterministic quantum theory. The classic analysis of the structure of the main elementary particle could be carried out, including the photon, and bypassing the wave function. It was found that the photon is a two-rotor relativistic particle and that its electrical and magnetic rotors exist simultaneously and are situated in the orthogonal polarisation planes. The intersection of the polarisation planes forms the main axis of the photon around which the polarisation waves can rotate. The main axis of the photon is directed in the direction of the speed vector of the movement of the photon in the quantised medium. In this form, the photon represents a wave–particle, some concentrated bunch of the electromagnetic energy of the quantised space-time, flying with the wave speed of light. The electromagnetic field of the photon satisfies the two-rotor Maxwell equation. Calculation parameters of the photon were determined for the first time: the strength of the electrical and magnetic fields in the rotors of the photon, the densities of the electrical and magnetic displacement currents, the currents themselves, and many other parameters which could not previously be calculated. It was found that deceleration of light in an optical medium is caused by the wave trajectory of the photon as a result of the probable capture by the photon of atomic centres of the lattice of the optical medium with the speed vector of the photon in the quantised medium not coinciding with the speed vector in the optical medium.

6.1. Introduction

This study is a continuation of analysis of new fundamental discoveries of the space-time quantum (quanton) and the superstrong electromagnetic interaction (SEI) for examination of the structure and parameters of the photon. Paradoxically, the radiation quantum (photon) was discovered more than 100 years before discovery of the space-time quantum (quanton), regardless of the fact that the photon is a secondary formation in the quantised space-time. In particular, the quantised space-time represents the unified Einstein field which is a carrier of superstrong electromagnetic interaction. New discoveries have been used as a basis for developing the theory of the elastic quantised medium (EQM) and the Superunification theory which combines all the known fundamental interactions [1, 2].

It should be mentioned that Einstein was at the origins of the quantum theory and he introduced the concept of the radiation quantum [3, 4]. Paradoxically, Einstein in particular did not accept the statistical nature of the wave function on which the modern quantum theory is based. This scientific approach was based on the classic perception of the phenomena and events, assuming the quantum theory should be predictable, i.e., deterministyic [5, 6].

Now it can be claimed with confidence that Einstein won this scientific battle. The discovery of the quanton has returned to the quantum theory the classic field as the unified electromagnetic field in the sense that all the quantum processes and events develop on the unified field inside the quantised space-time. The presence of the unified field makes it possible to change greatly the calculation apparatus of quantum theory, making it accessible and predictable. Several fundamental concepts were used to describe the nature and structure of the photon, three of which belong to Einstein:

1. The concept of the unified field which in the theory of the elastic quantised medium was emboddied into the quantised space-time [1, 2].
2. The concept of determinism in quantum theory
3. The concept of the photon as a specific wave-particle
4. Analysis of the Maxwell rotor equations

5. The Planck relationship between the radiation energy of the photon W and its frequency ν:

$$W = \hbar\nu \tag{6.1}$$

where $\hbar = 1.054 \cdot 10^{-34}$ J·s is the Planck constant.

All the previously mentioned fundamental concepts (with the exception of the Maxwell equations) relate to the beginning of the 20th century and have proved to be sufficient for developing the classic theory of the photon. In fact, no further fundamental concepts in the photon theory than those mentioned previously were proposed in the 20th century. The fact that the further development of the photon theory was postponed by almost 100 years is due to principal errors in the unjustified refusal of the light-bearing medium, and not only of Einstein but of the entire theoretical physics of the 20th century. This does not diminish Einstein's achievement in science because every scientist has a right to make an error and only those who do not do anything do not make any errors. The unjustified refusal of the light-bearing medium was the result of the inaccurate interpretation of the experiments carried out by Fizo and Michelson and Morley [1,2].

Paradoxically, it was Einstein who developed throughout all his scientific activities the concept of unification of space and time into a single concept of space-time, trying to combine electromagnetism and gravitation, with this concept used in refusal of the light-bearing medium. If we characterise the physics of the 20th century as a whole, regardless of considerable achievements of mainly the experimental type, a number of paradoxic situations occurred in theoretical physics, with one of them being the rejection of the light-bearing medium. In the final analysis this resulted in a new crisis in quantum theory because regardless of the huge investments into the development of the most powerful particle accelerators and quantum generators, the results of all subsequent investigations did not help physics to understand the structure of elementary particles, including the photon.

To remove the obstacles forming the development of quantum theory it was necessary to return to physics the light-bearing medium as the fundamental property of the quantised space-time. For this purpose, it was necessary to derive analytically the Maxwell equations which had previously been derived by Maxwell in the purely empirical form to provide a mathematical basis for the Faraday laws of electromagnetic induction of the analytical derivation is of the Maxwell equations was based only on the analysis of electromagnetic perturbation of the quantised space-time which is a carrier of the electromagnetic wave. It was proved that like light, the electromagnetic wave cannot propagate in the empty space [1, 2].

In particular, the inaccurate interpretation of the Maxwell rotor equations was used as an additional argument for ignoring the light-bearing medium, assuming inaccurately that the electromagnetic field is an independent substance which does not require a carrier in the form of the light-bearing medium. It was assumed that the rotor of the magnetic field generates the rotor of the electrical field, and vice versa, generating an electromagnetic wave. However, in [2] it was shown that this concept is not confirmed by experiments. The rotors of the magnetic and electrical fields exist simultaneously in the electromagnetic wave. This means that in the electromagnetic wave, in contrast to the laws of electromagnetic induction in electrical circuits, the magnetic field does not generate the electrical field and vice versa. The propagation of the electromagnetic wave in vacuum is due to the quantised space-time being a light-bearing medium [1].

Another paradox of modern physics is the incorrect interpretation of the propagation of light in optical media. This problem was often investigated in [2]. This book is concerned with the complete justification of the wave nature of movement of the photon in the optical medium along a wave-shaped trajectory. The movement of the photon in the optical medium is linked with the light-bearing quantised medium. The optical medium distorts the straight trajectory of the photon in the quantised medium, and prevents the photon from carrying out additional transverse oscillations inside the lattice of the optical medium. Consequently, moving in the quantised medium with the speed of light C_0 but, in this case, along the wave-shaped trajectory, the photon travels the same distance in the optical medium after a longer period of time that if the photon had travelled along a straight line. The effect of reducing the speed of the photon in the optical media takes place. In order to understand the nature of these phenomena, it was necessary to develop the two-rotor structure of the photon and link its parameters with equation (1) where the photon energy remains proportional only to the frequency of its electromagnetic field.

Of all the elementary particles the photon stands separately because it cannot be in the rest state, both absolute or relative. The photon exists only at the speed of light inside the quantised space-time representing a particle–wave and when arrested it disappears without a trace, transferring its energy momentum to the atom (molecule). The speed of the photon in the space-time non-perturbed by gravitation is a constant, $C_0 \approx 3 \cdot 10^8$ m/s. In the quantised space-time perturbed by gravitation the speed of the photon C decreases [1, 2]

$$C = C_0 \sqrt{1 - \frac{\gamma_n R_g}{r}} \tag{6.2}$$

where r is the distance from the centre of the gravitational perturbation to the coordinates in which the speed of light is determined, m; R_g is the gravitational radius of the perturbing mass m, m; g_n is the normalised relativistic factor

$$\gamma_n = \frac{1}{\sqrt{1-\left(1-\frac{R_g^2}{R_S^2}\right)\frac{v^2}{C_0^2}}} \tag{6.3}$$

$$R_g = \frac{Gm}{C_0^2} \tag{6.4}$$

where $G = 6.67 \cdot 10^{-11}$ Nm²/kg² is the gravitational constant; R_S is the radius of the gravitational boundary (radius of the perturbing mass), m; v is the speed of movement of the perturbing mass, m/s.

There is no other equation in physics, with the exception of (6.2), for determining the speed of the photon C. Equation (6.2) is governed by the principle of spherical invariance which postulates that all the solids retain the configuration of their gravitational field, irrespective of the speed of movement of the solid. There is no compression of the gravitational field in the direction of movement. This means that the speed of light on the surface of the Earth remains constant, irrespective of the horizontal orientation of the arms of the Michaelson interferometer. This was also recorded in the experiments carried out by Michaelson and Morley.

On the other hand, the principle of spherical invariance enables the Earth to be regarded as an independent local centre, determining the principle of the relative-absolute dualism when the principle of relativity is manifested as the fundamental property of the quantised space-time. The presence of energy bifurcation on the acceleration curve in transition from a non-inertial system to an inertial reference system, and vice versa, shows that the principle of relativity does not require any further additional experimental verification because it is found in almost all experiments with acceleration of solids (particles) [2].

Previously, it was reported in [2] that the experiments with the exclusion of the light-bearing medium had been formulated incorrectly. For this to be so it would be necessary to exclude the light-bearing medium along the path of the photon. This means that the exclusion of the light-bearing medium from physics was not justified. The exclusion of the hypothetical mechanistic aether with the properties of aether wind was justified because, as shown in the EQM theory, the former does not exist in nature. However, mechanistic aether has no relationship with the quantised space-time as a light-bearing medium.

However, the experiment which confirms that the failure of the light-bearing medium results in the disruption of its light conductivity has been formulated by the nature itself in astrophysics on the surface of a black hole. In fact, for a static black hole at $\gamma_n = 1$, the speed of light C (2) on the surface ($r = R_g$) is equal to 0. This means that the light cannot leave the black hole and penetrate into it, making it invisible. This is explained by the fact that the quantum density of the medium ρ_1 on the surface of the black hole is equal to 0, forming a discontinuity in the light-bearing medium. When falling onto a black hole, the photon slows down to zero and ceases to exist. Thus, the strong gravitational field of the black hole absorbs photons [2].

In particular, the presence of the light-bearing medium is a compulsory condition for the existence of a photon as a particle-wave. The nature and structure of the photon can be investigated only in the conditions of the quantised space-time. Information on the photon currently available is extremely rare and relates to its individual properties, such as: energy $\hbar\nu$(1), spin 1 $\hbar$, relativistic pulse $p = \hbar\nu/C$, the rest mass is equal to 0. The calculation mathematical apparatus is purely phenomenological and does not make it possible to derive specific calculation parameters of the photon for any wavelength nor clarify its structure [7].

6.2. Electromagnetic nature of the photon and rotor models

To determine the structure of the photon and its specific parameters in the conditions of the Maxwell classic electromagnetic field, it was necessary to analyse the state of the photon in the quantised space-time as its integral part. Since the photon does not have any rest mass and moves constantly with the speed of light C, we can only discuss the particle-wave in the quantised medium. However, this single wave is grouped in such a manner that it represents some wave energy bunch similar to a corpuscule, showing corpuscular-wave properties. For this reason, the photon cannot transfer a free electrical charge, like the electron, nor it can carry a free magnetic charge because of the absence of such in nature. These charges exist only as combined charges in the structure of the quanton and the quantised medium.

At present, the photon as a particle-wave does not cause any doubts as regards its existence, showing the corpuscular and wave properties. However, old stereotypes have not as yet been overcome here. In the photoeffect, the photon is regarded as a sphere. When studying the wave properties of the photon, the photon is regarded as identical with some wave electromagnetic packet, taking into account the classic considerations of the electromagnetic wave. The existing contradictions cannot be eliminated assuming that the photon-sphere in movement in the quantised medium transfers simultaneously the electromagnetic wave, but this wave should of course differ from the classic electromagnetic wave, regardless of the classic base.

To combine the structure of the photon-sphere and its electromagnetic wave field into a single structure, it was necessary to overcome the existing stereotypes and return to the analysis of the light-bearing medium which in the EQM theory is treated as an elastic quantised medium being the carrier of the superstrong electromagnetic interaction.

In [1], special attention was given to the nature of electromagnetism in the quantised medium, with the analytical derivation of the Maxwell equations for the classic electromagnetic waves of the continuous type. The simultaneous existence of the electrical and magnetic components in the electromagnetic wave can be explained only in the EQM theory on the basis of analysis of electromagnetic polarisation of the quantised medium where the displacement of the electrical charges in the quanton results in the simultaneous displacement of the magnetic charges, disrupting the magnetic equilibrium of the quantised medium, and vice versa. This can be expressed by the density of the currents of electrical $\mathbf{j}_e$ and magnetic $\mathbf{j}_g$ displacement of the electrical and magnetic charges in the quantised medium in the form of a vector product [1]

$$\left[\mathbf{C}_0\mathbf{j}_e\right] = \mathbf{j}_g \tag{6.5}$$

Equation (6.5) is the generalised unique Maxwell equations for vacuum, establishing the mutual orthogonality of three vectors $\mathbf{C}_0$, $\mathbf{j}_e$ and $\mathbf{j}_g$. The vectors $\mathbf{j}_e$ and $\mathbf{j}_g$ are situated in the plane orthogonal to the speed vector $\mathbf{C}_0$ in the direction of movement of the wave, determining the transverse nature of electromagnetic oscillations. Equation (6.5) can be written in the complex form through the harmonic variation of the vectors (with the dot) of the strength of the electrical $\dot{\mathbf{E}}$ and magnetic $\dot{\mathbf{H}}$ fields in the electromagnetic wave:

$$\varepsilon_0\left[\mathbf{C}_0\dot{\mathbf{E}}\right] = -\dot{\mathbf{H}} \tag{6.6}$$

where $\varepsilon_0 = 8.85\cdot10^{-12}$ F/m is an electrical constant.

The rotorless equation (6.6) can be easily transformed to a wave equation, showing that it is not necessary to use rotor equations for the formation of the electromagnetic wave in the quantised medium. However, rotors are present in the electromagnetic wave, and two rotors exist there simultaneously: electrical and magnetic, as required by the Maxwell equations. The two-rotor unified Maxwell equation for the electromagnetic wave, describing the simultaneous presence of the electrical and magnetic components, results from (6.6)

$$\varepsilon_0 C_0 \operatorname{rot} \mathbf{E} = -\operatorname{rot} \mathbf{H} \tag{6.7}$$

The nature of the equations (6.5)...(6.7) is determined by the fact that the electrical and magnetic charges inside a quanton are connected together electrically, ensuring the simultaneous circulation of the electrical and magnetic energies and determining the periodicity of circulation in the form of electromagnetic oscillations in the quantised medium [1].

Figure 6.1 shows the scheme of simultaneous circulation of the vectors **E** and **H** in the form of rotors (6.7) on the sphere of the electromagnetic wave in the orthogonal sections. The source of the spherical electromagnetic wave is situated in the centre 0. Any two orthogonal sections of the sphere of the wave give two diagonal points *a* and *b* with arbitrary coordinates. At the points *a* and *b* the vectors **E** and **H** are orthogonal to each other, and the rotors themselves (6.7) circulate in the orthogonal planes *Z*0*X* and *Y*0*X*, satisfying the equation (6.7). Regardless of the arbitrary coordinates of the diagonal points *a* and *b* defined on the sphere of the wave, the pattern of the electromagnetic field of the spherical wave is described by the scheme in Fig. 6.1 for the arbitrarily rotated figure in space [1].

The two-rotor differential vector equation (6.7) of the electromagnetic field in vacuum, if it is based on the unanimity of electromagnetic phenomena, should describe not only the spherical wave but also the electromagnetic field of the photon. However, by its nature, the spherical classical electromagnetic wave and the electromagnetic field of the photon have properties which differs greatly that it is unnatural to use the results for describing photon radiation.

The intensity of the classic electromagnetic wave is determined by the Pointing vector |**EH**|, which determines the volume density of

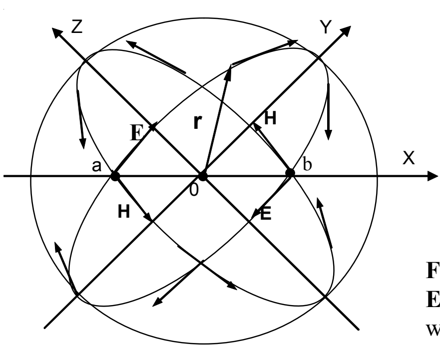

Fig. 6.1. Simultaneous circulation of the vectors **E** and **H** on the sphere of the electromagnetic wave in orthogonal sections.

electromagnetic energy W_v [1]:

$$W_v = \frac{EH}{C_0} \tag{6.8}$$

Equation (6.8) includes the moduli of the actual value of the strength of the electrical **E** and magnetic **H** fields of the electromagnetic wave irrespective of radiation frequency. The density of the volume energy in vacuum resulting from the static fields with the strength of the orthogonal vectors **E** and **H** is the same.

The intensity (radiation energy W) of photon radiation is proportional to its frequency (6.1) or inversely proportional to the wavelength $\lambda = C_0/\nu$:

$$W = \hbar\nu = \hbar\frac{C_0}{\lambda} \tag{6.9}$$

The independence of the intensity on radiation frequency (6.8) and its total dependence on frequency in (6.7) appear to be incompatible assumptions which should not result from the analysis of the unified differential equation (6.7) of the electromagnetic field. However, the initial conditions of irradiation of the spherical wave and photon radiation differ and, correspondingly, analysis of the equation (6.7) yields different results.

It is assumed that a spherical wave identical with that in Fig. 6.1 and described by the two-rotor equation (6.7) has been emitted by a relativistic electron. In fact, the orbital electron of the atom situated inside the gravitational well of the atomic nuclei can also be regarded as a relativistic electron. This problem is not investigated in this book because the theory of radiation of the orbital electron is a very large independent section of the theory of Superunification. It should only be mentioned that the presence of the gravitational well [2] in the atom nucleus explains the constancy of the energy of the electron–nucleus system when the increase of the electrical energy of the system for the case in which the electron and the nucleus come closer together is compensated by a decrease of the gravitational energy of the system. For this reason, the electron does not emit anything even on a greatly elongated orbit [8]. However, as shown by calculations, the orbital electron emits only when it reaches the limiting critical speed and acceleration in the vicinity of the atomic nucleus. In this case, the speed of the electron approaches the speed of light and determines the radiation of the orbital electron as the radiation of a relativistic particle.

It is one thing when the source of electromagnetic radiation is stationary or moves in the range of non-relativistic speeds, and the electromagnetic wave in space forms a classic spherical wave whose front increases and expands on the sphere with increasing distance from the source. It is quite another matter when the radiation source moves at relativistic speeds.

We consider a process in which the relativistic electron forms a two-rotor (6.7) spherical wave similar to that in Fig. 6.1 as a result of the transformation of the mass defect into electromagnetic radiation. The theory of relativity shows unambiguously that such a spherical wave, travelling at the speed of light, cannot expand like the classic spherical wave. This is the key point of the problem. The non-expanding wave electromagnetic sphere, travelling at the speed of light, is a photon in the form of a wave sphere-corpuscule whose diameter is constant. However, this is not a solid sphere but a sphere which includes two rotors (6.7), and represents a bunch of the energy of the electromagnetic polarisation of the quantised medium and the trace of its movement in the quantised medium leaves behind a single wave.

Evidently, there is a very short period of time within which the photon forms and is still capable of expanding in the range of speeds from the speed C inside the gravitational well at the final diameter at the moment of reaching the speed of light C_0. It can be assumed that high energy photons form at a higher rate, for example, in annihilation of the electron and the positron and, consequently, their diameter is smaller.

Thus, after irradiation and the formation of the final diameter at the speed of light, the two-rotor sphere-photon cannot expand any further and its diameter remains constant. It should be mentioned that the photon should be regarded as a particle with the spin equal to unity. This results from the equivalence between electricity and magnetism in the electromagnetic wave and the presence of two rotors at the photon, each of which characterises the particle with half spin and in the total ensures the total spin of the particle.

It is also necessary to take into account the rotation of orthogonal planes of polarisation of the photon in which the two previously mentioned rotors of electrical and magnetic polarisation of the medium are located. This rotation takes place around the axis in the direction of movement of the photon. Therefore, the photon as a two-rotor particle with the rotation of the polarisation planes is similar to a spherical particle-corpuscule. This particle in the quantised medium should also be governed by the principle of spherical invariance in retaining its spherical form and diameter. We consider in greater detail the corpuscular and wave properties of the photon with the two-rotor structure.

Figure 6.2 shows the two-rotor structure of the photon with the rotation of the polarisation planes in the right angled coordinate. The direction of the speed of movement of the photon $\mathbf{C}_0$ coincides with the main axis X. The rotors $\mathbf{E}$ and $\mathbf{H}$ are situated in the orthogonal polarisation planes $Y0X$

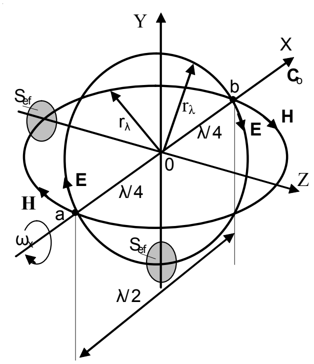

Fig. 6.2. The two-rotor structure of the photon with the rotation of the polarisation planes.

and $Z0X$ and make contact in the vicinity of the diagonal points a and b. The polarisation planes rotate around the main axis X with the cyclic frequency ω_x which is not connected directly with the frequency of circulation of the rotors of the electromagnetic field. Evidently, the flux of the circulation vectors is determined by the effective cross-section of the rotors S_{ef}. This is one of the main new parameters of the photon which has not been examined previously and must be taken into account in further calculations.

Analysis of the quantised structure of the photon in Fig. 6.2 shows that the photon may represent a half-wave two-rotor volume electromagnetic resonator and the circulation of the vectors of the strength of the electrical **E** and magnetic **H** fields of the resonator is determined by the constancy of the electromagnetic energy of the photon. This is achieved by the anti-phase variation of the electrical and magnetic energy of the photon when the increase of the magnetic component results in a decrease of the electrical component, and vice versa. The half-wave resonator is one of the two models of the photon because the all-wave model can be accepted in this case.

It was shown in [1] that all wave electromagnetic processes in the quantised medium are connected with the circulation of the electrical and magnetic energies in the anti-phase and, at the same time, ensure its constancy. This also relates to the photon determining the constancy of its energy at the given frequency. The vectors **E** and **H** are derivatives of the variation of energy, regardless of the decrease or increase of the electrical and magnetic components of the photon energy.

Therefore, with the general energy of the photon constant, the variation of the electrical and magnetic components results in a simultaneous manifestation of the vectors **E** and (–**H**) in the anti-phase, ensuring circulation of the vectors around the rotor in the polarisation planes. In the case of the vectors **E** and **H** the sign of the direction of circulation is important. This sign changes periodically and determines the direction of circulation in the clockwise or anticlockwise direction. The circulation of the vectors **E** and **H** is mutually connected by the two-rotor Maxwell equation (6.7) with both equations determining the density of the fluxes of the electrical $\mathbf{j}_e$ and magnetic $\mathbf{j}_g$ displacement (6.5) in the rotor [1]

$$\begin{cases} \mathbf{j}_e = \operatorname{rot}\mathbf{H} = \varepsilon_0 \dfrac{\partial \mathbf{E}}{\partial t} \\ \mathbf{j}_g = \dfrac{1}{\mu_0}\operatorname{rot}\mathbf{E} = -\dfrac{\partial \mathbf{H}}{\partial t} \end{cases} \tag{6.10}$$

where $\mu_0 = 1.26 \cdot 10^{-6}$ H/m is a magnetic constant.

The variation of the vectors **E** and **H** with time for the photon which represents a relativistic electromagnetic resonator in the quantised medium should take place in accordance with the harmonic law: sinusoidal or cosinusoidal. Since the primary disruption of electromagnetic equilibrium of the quantised medium is associated with the displacement of the charge in accordance with the sinusoidal law, it is accepted that the variation of the strength of the field is determined by the cosinusoidal function [1]:

$$\begin{cases} \mathbf{E} = \mathbf{E}_a \cos 2\pi\nu t \\ \mathbf{H} = \mathbf{H}_a \cos(-2\pi\nu t) \end{cases} \qquad \mathbf{E} \perp \mathbf{H} \tag{6.11}$$

In (6.11), the vectors **E** and **H** are treated as instantaneous with respect to time, and the vectors $\mathbf{E}_a$ and $\mathbf{H}_a$ represent their amplitude values. Consequently, the first derivative with respect to time of (6.11) is determined by the density of the bias currents $\mathbf{j}_e$ and $\mathbf{j}_g$ which already vary in accordance with the sinusoidal law (T is the oscillation period)

$$\begin{cases} \mathbf{j}_e = \varepsilon_0 \dfrac{\partial \mathbf{E}}{\partial t} = -2\pi\varepsilon_0\nu\mathbf{E}_a \sin\left(\dfrac{2\pi}{T}t\right) \\ \mathbf{j}_g = -\dfrac{\partial \mathbf{H}}{\partial t} = 2\pi\nu\mathbf{H}_a \sin\left(\dfrac{2\pi}{T}t\right) \end{cases} \qquad \mathbf{j}_e \perp \mathbf{j}_g \tag{6.12}$$

In (6.4) the vectors $\mathbf{j}_e$ and $\mathbf{j}_g$ carry out oscillations in the anti-phase and, therefore, the sign (–) in calculations is retained either in (6.10) or in (6.11). In transition from instantaneous values to actual moduli, equation (6.12) gives

$$\begin{cases} j_e = 2\pi\varepsilon_0 E \cdot \nu \\ j_g = 2\pi H \cdot \nu \end{cases} \tag{6.13}$$

As indicated by (6.13), the densities of the currents in the rotors of the photon are proportional to the strength and frequency of the field. On the other hand, the energy of the photon W (6.19) is proportional only to frequency ν. It is therefore necessary to determine the conditions in which the electromagnetic parameters of the photon in the Maxwell equations ensure that the energy of the photon is proportional only to the frequency of the field. For this purpose, equation (6.8) is integrated

$$W = \int_V W_v dV = \int_V \frac{EH}{C_0} dV \tag{6.14}$$

If the rotor of the photon is regarded as a homogeneous torus ('bagel') with the effective cross-section S_{ef} and the mean length of the line of force ℓ of the tube of the rotor around the circumference, the integral (6.14) can be transformed

$$W = \int_V \frac{EH}{C_0} dV = \frac{1}{C_0} \iint EH d\ell dS = \frac{EH}{C_0} \ell S_{ef} \tag{6.15}$$

Equation (6.15) is equated with (6.9) and we determine the conditions in which the electromagnetic parameters of the photon satisfy the condition of proportionality of the energy to the frequency of the field

$$\frac{EH}{C_0} \ell S_{ef} = \hbar \nu \tag{6.16}$$

$$\frac{EH}{C_0} \frac{\ell S_{ef}}{\nu} = \hbar = \text{const} \tag{6.17}$$

Condition (6.17) determines the electromagnetic parameters of the photon at which the photon energy is proportional to frequency. From equation (6.17) it is now necessary to remove the frequency of the field ν and replace it by the wavelength $\nu = C_0/\lambda$

$$\frac{EH}{C_0} \frac{\ell \lambda S_{ef}}{C_0} = \hbar = \text{const} \tag{6.18}$$

In the condition (6.18) the wavelength λ and the length of the mean line of force ℓ of the tube of the rotor of the photon as linear parameters are connected by the relationship (here k_λ is the coefficient of the wavelength of the photon)

$$k_\lambda = \frac{\lambda}{\ell} \tag{6.19}$$

From (6.19) we replace in (6.18) $\lambda = k_\lambda \ell$:

$$\frac{E\ell H\ell}{C_0^2} k_\lambda S_{ef} = \hbar = \text{const} \tag{6.20}$$

Equation (6.20) includes the rotor (circular) electrical φ_e and magnetic φ_g potentials (actual values) of the photon

$$\varphi_e = E\ell, \quad \varphi_g = H\ell \tag{6.21}$$

The electrical φ_e and magnetic φ_g potentials (6.21) determine the difference of the potentials (voltage) circulating in the turn of the photon rotor (the dimension is potential per turn). Substituting (6.21) into (6.20) we obtain a more exact condition in which the photon energy is proportional to the field frequency

$$\frac{\varphi_e \varphi_g}{C_0^2} k_\lambda S_{ef} = \hbar = \text{const} \tag{6.22}$$

The rotor potentials (6.22) φ_e and φ_g per the turn of the photon rotor, are induction potentials and should not depend on the length of the rotor turn (as in a transformer) and are constants which will be the same for all the photons, emitted by the electron

$$\varphi_e = \text{const}, \quad \varphi_g = \text{const} \tag{6.23}$$

$$\frac{\varphi_e \varphi_g}{C_0^2} = \text{const} \tag{6.24}$$

If a turn made from a conductor could be installed in the electrical rotor, the difference of the electrical potentials, equal to the rotor potential φ_e, would be induced at the ends of the turn. The rotor potentials (6.23) are measured: electrical φ_e in volts (V) and magnetic φ_g in amperes (A). The magnetic potential in the SI system is a derivative of the magnetic moment which has the dimension [Am^2 = Dc·m]. In the EQM theory, the magnetic potential is determined by the magnetic charge g whose dimension is [Dc = A·m]. This shows that the dimension of the magnetic potential is [A], as that of electrical current, because the magnetic parameters in the SI system are derivatives of electrical current [1].

Constant (6.24) is included in (6.22). This shows that the product $k_\lambda S_{ef}$ should also be a constant

$$k_\lambda S_{ef} = \text{const} \tag{6.25}$$

Thus, the condition (6.22) should include only one constant to ensure that the photon energy remains proportional to the frequency of the electromagnetic field. Of the six parameters included in (6.22) only two are known: C_0^2 and $\hbar$. Taking into account the symmetry between electricity and magnetism of the photon, the magnetic parameters can be reduced to electrical ones:

$$\varphi_g = \varepsilon_0 C_0 \varphi_e \tag{6.26}$$

In (6.22) we replace the magnetic potential φ_g and leave only one parameter in the condition (6.22)

$$\frac{\varepsilon_0 \varphi_e^2}{C_0} k_\lambda S_{ef} = \hbar = const \tag{6.27}$$

The new condition (6.27) of proportionality of the photon energy to the field frequency contains three unknown parameters: φ_e, k_λ and S_{ef}, two of which, k_λ and S_{ef}, are related to the photon geometry. Figure 6.2 shows the two-rotor structure of the photon and also that the rotors circulate in two orthogonal polarisation planes. Subsequently, it was assumed that the rotor has the form of a torus ('bagel').

The complicated geometrical form of the proton indicates that the electrical and magnetic fields inside the torus are distributed nonuniformly in the cross-section of the torus. In this case, the conditions of proportionality of the photon energy to the field frequency should be written in the integral form (6.14). However, the functional distribution of the field in the cross-section of the torus inside the rotor is not known. Therefore, it was decided to transfer to the actual values of the electromagnetic parameters of the photon, assuming that the field in the cross-section of the torus inside the rotor is distributed uniformly. In this case, the cross-section of the rotor S_{ef} is calculated, like the effective (actual) cross-section which does not reflect the total cross-section of the torus S_t. The effective cross-section of the rotor S_{ef} and the total cross-section of the torus S_t are different cross-sections which can be connected by the coefficient of the cross-section of the rotor k_s, and k_s<1

$$S_{ef} = k_s S_t \tag{6.28}$$

Naturally, if we know the geometry of the photon rotors and its connection with the wavelength (6.19) and cross-section of the rotors (6.28), we can determine the unknown geometrical parameters k_λ and S_{ef} in the condition (6.27). For this analysis it is necessary to select a photon whose parameters are determined by the distinctive geometry, on the basis of the limiting initial conditions which are available. These known geometrical parameters should be characteristic of the gamma quantum with the energy of 0.511 MeV produced as a result of annihilation of the electron.

When the electron annihilates to a gamma quantum with the maximum radiation energy for electron of 0.511 MeV, the energy, which exceeds this

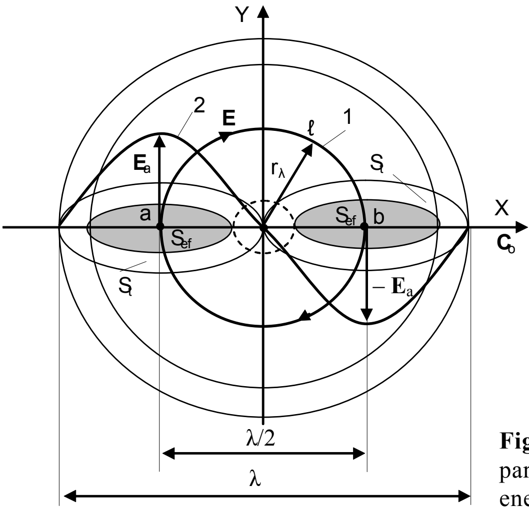

Fig. 6.3. Calculation of the geometrical parameters of a gamma quantum with the energy of 0.511 MeV.

limiting value, cannot be emitted by the electron. Evidently, in the limiting case, the photon rotor for the given gamma quantum should occupy the maximum possible volume of the photon, having the form of a torus in the form of a bagel without any orifice in the centre.

Figure 6.3 shows the calculation diagram of the geometrical parameters of the gamma quantum with the energy of 0.511 MeV for the electrical rotor of the photon at the speed C_0 on the axis X. The torus of the rotor with the section S_t occupies the maximum possible volume of the photon. Previously, all the calculation parameters of the photon were related to the mean length ℓ of the force tube of the rotor with the cross-section S_{ef} represented by a circle 1 with the radius r_λ. It was assumed that the parameters of the strength **E** of the electrical field of the local are uniformly distributed throughout its effective cross-section S_{ef}.

In reality, the photon can leave a wave electromagnetic trace in the quantised medium which is described by the harmonic function (curve 2 in Fig. 6.3) of the wavelength λ for the strength of the field **E**. The harmonic function is given for the moment of time when the circulation of vector **E** in the rotor reaches the amplitude value $\mathbf{E}_a$. As a result of analysis, the calculation scheme can be used to determine the geometrical parameters of the gamma quanta with the energy of 0.511 MeV. It may be seen that the mean length of the force tube of the rotor ℓ is determined by the radius $r_\lambda = \lambda/4$

$$\ell = 2\pi r_\lambda = \frac{\pi}{2}\lambda \tag{6.29}$$

Substituting (6.29) into (6.19) we determine the required coefficient k the wavelength of the photon

$$k_\lambda = \frac{\lambda}{\ell} = \frac{2}{\pi} = 0.64 \tag{6.30}$$

The wavelength λ_0 of the annihilation gamma quantum of the electron, equal to the Compton wavelength of the electron λ_0, is determined from the condition of equivalence of the photon energy and electron mass

$$\hbar\frac{C_0}{\lambda_0} = m_e C_0^2 \tag{6.31}$$

$$\lambda_0 = \frac{\hbar}{m_e C_0} = 3.86 \cdot 10^{-13}\,\mathrm{m} \tag{6.32}$$

The cross-sectional area S_t of the torus of the rotor is determined from the equality of the diameter d_t of the torus to half the wavelength $d_t = \lambda_0/2$ (Fig. 6.3)

$$S_t = \frac{\pi d_t^2}{4} = \frac{\pi\lambda_0^2}{16} = 2.93 \cdot 10^{-26}\,\mathrm{m}^2 \tag{6.33}$$

The calculation area of the effective cross-section S_{ef} of the force tube of the rotor is determined from the condition of the equality of electrical fluxes for the homogeneous and inhomogeneous fields, penetrating through the sections S_{ef} and S_t. In Fig. 6.3, the effective cross-section S_{ef} its dark. The flux of the electrical field penetrating the actual effective cross-section S_{ef} is homogeneous and determined by the actual value of the strength of the field **E**. The heterogeneous flux of the electrical field penetrating the maximum cross-section S_t is determined by the harmonic function **E** in the cross-section. If the fluxes are equal, it can be seen that the effective section S_{ef} is $\sqrt{2}$ times smaller than the maximum cross-section S_t, according to the coefficient $k_s = 1/\sqrt{2}$ (6.28)

$$S_{ef} = k_s S_t = \frac{S_t}{\sqrt{2}} = \frac{\pi\lambda^2}{16\sqrt{2}} = 2.07 \cdot 10^{-26}\,\mathrm{m}^2 \tag{6.34}$$

Substituting the geometrical parameters of the photon: coefficient k_λ (6.30) and the cross-section S_{ef} (6.34) of the photon rotor into the condition (6.27) of the proportionality of the photon energy to the field frequency, we determine the last unknown parameter: the rotor electrical potential φ_e

$$\varphi_e = \sqrt{\frac{\pi\hbar C_0}{2\varepsilon_0 S_{ef}}} = 0.521\ \text{MV} \tag{6.35}$$

The determined rotor potential $\varphi_e = 0.521$ MV is a constant for the photons emitted by the electron and is almost identical with the electrical potential 0.511 MV of the electron on its gravitational boundary determined by the classic radius $r_e = 2.82\cdot10^{-15}$ m. The small difference between 0.521 MV (6.35) and 0.511 MV is the error of calculation and can be subsequently removed. Therefore, for calculations in practice, the rotor potential for the photons emitted by the electron is represented by the electrical potential 0.511 MV on the gravitational boundary of the electron

$$\varphi_e = 0.511\ \text{MV} = \text{const} \tag{6.36}$$

From (6.36) we determine the rotor magnetic potential φ_g of the photon

$$\varphi_g = \varepsilon_0 C_0 \varphi_e = 1.36\cdot10^3\ \text{A} \tag{6.37}$$

Consequently, it can be seen that the process of formation of the photon by the electron, as assumed previously, is connected with the gravitational boundary of the electron and its electrical potential is induced on the photon as the rotor potential irrespective of the photon energy. This is the main parameter of the photon which determines the proportionality of its energy to the field frequency.

It was shown in [1] that for a classic electromagnetic wave spherically propagating in the space from the radiation source, the density of volume energy decreases in inverse proportion to the square of the distance irrespective of the field frequency. For the photon, the density of the volume energy is a constant value for every field frequency.

Taking into account the exact value of the rotor potential $\varphi_e = 0.511$ MV (6.36) of the photon, from (6.27) we determine the effective cross-section S_{ef} of the proton of the photon for $k_\lambda = 2/\pi$

$$S_{ef} = \frac{\pi\hbar C_0}{2\varepsilon_0 \varphi_e^2} = 2.15\cdot10^{-26}\ \text{m}^2 \tag{6.38}$$

From (6.38) we determine the calculation parameter d_s of the photon rotor for the effective cross-section S_{ef}

$$d_s = \sqrt{\frac{4S_{ef}}{\pi}} = 1.65\cdot10^{-13}\ \text{m} \tag{6.39}$$

The calculation results presented previously were obtained for the model of a photon rotor in the form of a torus. However, identical results can be obtained regarding the model of the photon rotor in the form of a disc. In addition, the disc model better corresponds to the flat model of the rotor when placed in the polarisation planes. In any case, for calculations it is necessary to determine the value of the effective cross-section S_{ef} (6.38) of the photon rotor and the value of the rotor potential $\varphi_e = 0.521$ MV (6.36), which is the initial value in calculation of new constants of the photon.

Of the eight constants characterising the photon and presented in Table 3.1, only the first two constants were known initially: the Planck constant and the spin. These two constants are sufficient for estimating the strength of the electrical and magnetic fields of the photon. Taking into account the small dimensions of the photon, it is not possible to introduce measuring probes into the region of its rotor electromagnetic fields to measure the strength of the field. For this reason, quantum electrodynamics is restricted to calculations of the energy of the photon, its momentum and frequency. Table 6.1 gives the constants characterising the photon.

Table 6.1. Photon constants

Parameter	Value
1. Planck constant $\hbar$	$\hbar = 1.054 \cdot 10^{-34}$ J·s
2. Spin S	$S = 1\hbar$
3. Rotor electrical potential φ_e	$\varphi_e = 0.511 \cdot 10^6$ V (36)
4. Rotor magnetic potential φ_g	$\varphi_g = 1.36 \cdot 10^3$ A (37)
5. Effective cross section of rotor S_{ef}	$S_{ef} = 2.15 \cdot 10^{-26}$ m^2 (38)
6. Calculated rotor diameter d_s	$d_s = 1.65 \cdot 10^{-13}$ m (39)
7. Wavelength coefficient k_λ	$k_\lambda = \lambda / \ell = 2/\pi = 0.64$ (30)
8. Rotor cross section coefficient k_s	$k_s = 1/\sqrt{2} = 0.707$ (34)

Until now, the quantum theory did not have at its disposal methods of estimating the potentials and strength of the electrical and magnetic fields of the photon. The procedures for calculating the electromagnetic parameters of the photon are presented for the first time, regardless of the fact that methods of measuring them in experiment are not yet available.

As an example, we can estimate the specific electromagnetic parameters of the photon in red light for a helium–neon laser with a wavelength of λ = 630 nm ($0.63 \cdot 10^{-6}$ m) and the frequency $\nu = 0.48 \cdot 10^{15}$ Hz. The electromagnetic parameters of the photon are calculated using the procedure described below and the constants from Table 6.1:

1. We determine the photon energy for the wavelength λ = 630 nm from (6.9)

$$W = \hbar\nu = \hbar\frac{C_0}{\lambda} = 5.02 \cdot 10^{-20}\,\text{J} = 0.31\,\text{eV} \tag{6.40}$$

2. We determine the mean length ℓ of the lines of force of the tube of the photon rotor by means of the wavelength λ and the coefficient of the wavelength k_λ:

$$\ell = \frac{\lambda}{k_\lambda} = \frac{\pi}{2}\lambda = 0.99 \cdot 10^{-6}\,\text{m} \tag{6.41}$$

3. The actual value of the strength of the electrical field E of the photon rotor is determined by means of the rotor electrical potential vector φ_e = $0.511 \cdot 10^6$ V (6.36) and the mean length ℓ (6.41) of the line of force

$$E = \frac{\varphi_e}{\ell} = \frac{2\varphi_e}{\pi\lambda} = 0.516 \cdot 10^{12}\,\frac{\text{V}}{\text{m}} \tag{6.42}$$

4. The actual value of the strength H of the magnetic field of the photon rotor is determined by means of the rotor magnetic potential φ_g = $1.36 \cdot 10^3$ A (6.37) and the mean length ℓ (6.40) of the line of force from (6.16) and (6.42)

$$H = \frac{\varphi_g}{\ell} = \frac{2\varphi_g}{\pi\lambda} = 1.37 \cdot 10^9\,\frac{\text{A}}{\text{m}} \tag{6.43}$$

$$H = \varepsilon_0 C_0 E = 1.37 \cdot 10^9\,\frac{\text{A}}{\text{m}} \tag{6.44}$$

5. The volume density of electromagnetic energy W_v (6.8) is determined from E (6.42) and H (6.43)

$$W_v = \frac{EH}{C_0} = 2.36 \cdot 10^{12}\,\frac{\text{J}}{\text{m}^3} \tag{6.45}$$

6. We verify the correspondence of the electromagnetic energy (6.15) of the photon, circulating in the rotors, to the energy (6.40)

$$W = \int_V \frac{EH}{C_0}dV = \frac{EH}{C_0}\ell S_{ef} = 5.02 \cdot 10^{-20}\,\text{J} \tag{6.46}$$

7. From equation (6.13) we determine the density of the electrical j_e and magnetic j_g bias currents in the photon rotors

$$j_e = 2\pi\varepsilon_o E \cdot \nu = 1.38 \cdot 10^{16}\,\frac{\text{C}}{\text{s·m}^2} = \left[\frac{\text{A}}{\text{m}^2}\right] \tag{6.47}$$

$$j_g = 2\pi H \cdot \nu = 4.13 \cdot 10^{24} \frac{\text{Dc}}{\text{s·m}^2} = \left[\frac{\text{A}}{\text{s} \cdot \text{m}}\right]$$
$$j_g = C_0 j_e = 4.14 \cdot 10^{24} \frac{\text{Dc}}{\text{s·m}^2} \tag{6.48}$$

8. We determine the values of the electrical I_e and magnetic I_g currents in the photon rotors

$$I_e = j_e S_{ef} = 2.97 \cdot 10^{-10} \frac{\text{C}}{\text{s}} = [\text{A}] \tag{6.49}$$

$$I_g = j_g S_{ef} = 8.9 \cdot 10^{-2} \frac{\text{Dc}}{\text{s}} = \left[\frac{\text{A·m}}{\text{s}}\right]$$
$$I_g = C_0 I_e = 8.9 \cdot 10^{-2} \frac{\text{Dc}}{\text{s}} \tag{6.50}$$

9. We determine the reactive (wave) resistance of the electrical Z_e and magnetic Z_g rotors of the photon

$$Z_e = \frac{\varphi_e}{I_e} = 1.72 \cdot 10^{15}\,\text{ohm} \tag{6.51}$$

$$Z_g = \frac{\varphi_g}{I_g} = 1.53 \cdot 10^{4} \frac{\text{A·s}}{\text{Dc}} = \left[\frac{\text{s}}{\text{m}}\right]$$
$$Z_g = \varepsilon_0 Z_e = 1.52 \cdot 10^{4} \frac{\text{s}}{\text{m}} \tag{6.52}$$

10. We determine the reactive powers: electrical Q_e and magnetic Q_g, circulating in the photon rotors:

$$Q_e = I_e \varphi_e = 1.52 \cdot 10^{-4}\,\text{VA} \tag{6.53}$$

$$Q_g = \mu_0 I_g \varphi_g = 1.52 \cdot 10^{-4}\,\text{VA} \tag{6.54}$$

The calculation equations presented above can be written in the differential, integral and complex forms, increasing the number of parameters which characterise the photon. At the moment, this is not important. It is important to show the physical nature of the processes, taking place in the photon rotors, without overloading the material with calculations.

It has been reliably established that the electromagnetic parameters of the photon can be calculated, confirming the deterministic nature of the quantum theory when investigating the parameters of single particles, as postulated by Einstein. Naturally, in cases in which the quantum theory operates with a large number of particles, the group behaviour of the particles can be evaluated by the statistical methods using the wave function when the physical laws of behaviour of the particles in the group are not known.

The fundamental physical laws include the law of electromagnetic induction represented by the Maxwell equations in which the large number of the quantons behave in an adequate manner resulting in the disruption of electromagnetic equilibrium in the quantised medium which can be described in a deterministic manner from the position of the causality of the phenomenon. The EQM theory operates with the colossal concentration of the particles (quanton), characterised by the quantum density of the medium which reaches the values of the order of 10^{75} particles/m^3.

The highest concentration of the quantons in the medium determines physical laws regarding them as some mean statistical parameters establishing a compromise between chaos and order in the quantised medium. For the physical laws to operate, there should be a specific degree of spontaneous freedom of the behaviour of the particles, characterising some chaos as the possibility of selecting the action or interaction. To ensure that the behaviour of the particles does not extend outside the limits restricting the uncontrolled intensification of spontaneous chaos, it is necessary to have restraining forces determined by physical laws from the position of determinism. In particular, the possibility of equilibrium between chaos, as the freedom of selection, and determinism, as a law restricting chaos, determines the established state of the particles (their stability or instability) in the quantised medium. This also relates to the photon.

Analysing the stable state of the photon for $\lambda = 630$ nm, it is important to mention that regardless of the very small value of the electrical $I_e = 2.97 \cdot 10^{-10}$ A (6.49) and magnetic $I_g = 8.9 \cdot 10^{-2}$ Dc/s (6.50) currents circulating in the photon rotors, the density of the currents $j_e = 1.30 \cdot 10^{16}$ A/m^2 (6.47) and $j_g = 4.14 \cdot 10^{24}$ Dc/cm^2 (6.48) and also the strength of the fields $E = 0.516 \cdot 10^{12}$ V/m (6.42) and $H = 1.37 \cdot 10^{9}$ A/m (6.43) reach colossal values because of the small dimensions of the photon and high energy concentration in the volume $W_v = 2.36 \cdot 10^{12}$ J/m^3 (6.45).

Comparing the diameter $d_s = 1.65 \cdot 10^{-13}$ m (6.39) of the effective cross-section of the rotor S_{ef}, for example, with the wavelength $\lambda = 630$ nm ($0.63 \cdot 10^{-6}$ m) of the light photon, we determine their ratio

$$\frac{d_s}{\lambda} = 2.6 \cdot 10^{-6} \tag{6.55}$$

In particular, in the range of low energy of the photons emitted by the orbital electron in the optical range conditions are created in which the diameter of the effective cross-section S_{ef} of the proton remains incommeasurably small (6.55) with the increase of the wavelength of the photon in comparison with the wavelength λ. This enhances the effect of the rotor potential of 0.511 MV on the fulfilment of the condition (6.27) which determines the law of proportionality of the photon energy to the field frequency.

If the photon rotors is not a torus and has the form of a disc we can estimate the thickness h_λ of the disc for λ = 630 nm, assuming that its radius is equal to half the wavelength λ/2, and the cross-section of the disc in the direction of the radius is represented by the effective cross-section $S_{ef} = 2.15\cdot10^{-26}$ m² (6.38)

$$h_\lambda = \frac{2S_{ef}}{\lambda} = 3.4\cdot10^{-20}\,\mathrm{m} \tag{6.56}$$

The result (6.56) does not contradict the EQM theory because the quanton diameter is of the order of 10^{-25} m and the disk of the rotor contains approximately 10^5 layers of quantons because the quanton is part of the polarised quantised medium. It has been established that the characteristic feature resulting from the increase of the wavelength for photon radiation is the compression of the polarisation plane in the disc model. This also ensures that the photon energy is proportional to the field frequency.

Table 6.2 shows the calculation parameters of the photon at λ= 630 nm. The parameters of the photon for λ = 630 nm, presented in Table 3.2, correspond to the condition of proportionality of its energy to the frequency of the electromagnetic field, and this can be confirmed by means of classic considerations on the basis of analysis of the unified field.

The main difference between the models of the photon with the rotor in the form of a torus or a disc is the photon diameter. For the disc model of the rotor, the diameter of the photon d_λ is determined by the wavelength λ, and the radius r_λ of the mean line of the rotor ℓ is equal to half the wavelength λ/2

$$\begin{aligned} d_\lambda &= \lambda \\ r_\lambda &= \lambda/2 \end{aligned} \tag{6.57}$$

Table 6.2. Calculation of electromagnetic parameters of the photon, λ = 630 nm

Parameter	Electrical	Magnetic
1. Field strength	$E = 0.516\cdot10^{12}$ V/m (6.42)	$H = 1.37\cdot10^{9}$ A/м (6.43)
2. Current density	$j_e = 1.38\cdot10^{16}$ A/m² (6.47)	$j_g = 4.14\cdot10^{24}$ Dc/s m² (6.48)
3. Current intensity	$I_e = 2/97\cdot10^{-10}$ A (6.49)	$I_g = 8.9\cdot10^{-2}$ Dc/s (6.50)
4. Reactive power	$Q_e = 1.52\cdot10^{-4}$ VA (6.53)	$Q_g = 1.52\cdot10^{-4}$ VA (6.54)
5. Wave resistance	$Z_e = 1.72\cdot10^{15}$ ohm (6.51)	$Z_e = 1.52\cdot10^{4}$ s/m (6.52)
6. Thickness of rotor disk	$h_\lambda = 3.4\cdot10^{-20}$ m (6.56)	$h_\lambda = 3.4\cdot10^{-20}$ m (6.56)
7. Formation time	$t_\lambda \approx 10^{-15}$ s (6.59)	$t_\lambda \approx 10^{-15}$ s (6.59)

Diameter (6.57) characterises the wave model. For the model of a light photon with the rotor in the form of a torus when the radius r_λ of the mean line ℓ of the rotor is equal to half the wavelength $\lambda/2$ and determines the diameter d_λ of the half-wave model we obtain

$$\begin{aligned} d_\lambda &= \lambda/2 \\ r_\lambda &= \lambda/4 \end{aligned} \tag{6.58}$$

Theoretically, both the wave (6.57) and half-wave (6.58) models of the photon are working models. However, preference is given to the wave model which is more universal, although some properties of the photon are explained by the half-wave model. The wave model explains electromagnetic parameters of the photon both in the region of low energies of the optical range and in the region of high energies of gamma quanta, representing the cross-section of the rotor in the form of a changing ellipse. In the region of low photon energies, the ellipse of the cross-section of the rotor is elongated representing the rotor in the form of flat disks situated in the orthogonal polarisation planes. In the region of high energies, a decrease of the wavelength results in expansion of the ellipse of the rotor cross-section into a circle and the rotor itself in the limiting case transforms into a torus. This is dictated by the conditions of proportionality of the photon energy to the field frequency. The half-wave model of the photon theoretically represents the averaged-out model of the photon which is connected with the mean length ℓ of the rotor and is suitable for simplified calculations.

As already mentioned, the electron forms photon radiation at the speed C slightly lower than the speed of light C_0. This is the range of the speed and time in which the photon can spherically expand. For this reason, the photons with high energy have small diameters because they form at a higher rate. We can estimate the time t_λ, assuming that spherical expansion of the photon from the gravitational boundary of the electron to the diameter determined by the wavelength (6.57) takes place with the mean speed $(C + C_0)/2$, which is very close to the speed of light C_0

$$t_\lambda \approx \frac{\lambda/2}{C_0} \approx \frac{\lambda}{2C_0} = \frac{\hbar}{2W} \tag{6.59}$$

Thus, for the photon with $\lambda = 630$ nm (red light) the duration of formation is $t_\lambda \approx 10^{-15}$ s, and for a gamma quantum with $\lambda = 3.86 \cdot 10^{-13}$ m it is $t_\lambda \approx 0.64^{-21}$ s. Equation (6.59) confirms that the rate of the high-energy processes is considerably higher than that of low-energy ones. This also applies to the processes of formation of photons in which the photons with high energies form on the electron many times faster than the low-energy photons.

6.3. Electromagnetic trace of the photon in the quantised medium

After discussing the electrical and magnetic parameters of the two-rotor structure of the photon (Tables 6.1 amd 6.2), it is necessary to show the wave nature of the photon which becomes evident when a flying photon leaves a trace in the quantised medium in the form of an electromagnetic wave. Figure 6.3 shows the possible wave trace of a photon on the X axis as a result of circulation of the vector of the strength **E** in accordance with the harmonic law. However, on the X axis, the vector **E** is transverse in relation to the direction of movement of the photon. This is consistent with the Maxwell equations which regard the electromagnetic wave oscillations as transverse oscillations of the vectors **E** and **H** in the orthogonal planes. However, in addition to the transverse components of circulation of the vectors **E** and **H**, the photon also has its longitudinal components which are not found in the classic electromagnetic wave.

Figure 6.4 shows the scheme of stage by stage circulation of the instantaneous vector of strength **E** of the electrical field in the rotor of a photon flying with the speed of light $\mathbf{C}_0$ in the direction of the X axis. The plane of the electrical polarisation of the photon is represented by the axes XY in the rectangular coordinate system. The positive value of the vector of strength **E** is represented by the direction of its circulation in the clockwise direction. This direction is maintained in the first half period of the oscillations of the time range from 0 to π for the total period 2π. In the second half period of the oscillations, the direction of the circulation of the vector of strength **E** of the field changes to the opposite direction. This anticlockwise direction of rotation is regarded as the negative direction of circulation of the vector of strength **E** in the range of the second half period from to 2π.

We examine individual stages of the variation of the instantaneous strength **E** in any region of the rotor in accordance with the harmonic law (6.11) for the period T in the range from 0 to 2π at the wavelength λ with the photon travelling at the speed of light in the quantised medium. In this case, analysis can be carried out more efficiently when the variation of the strength **E** is determined by the sinusoidal function

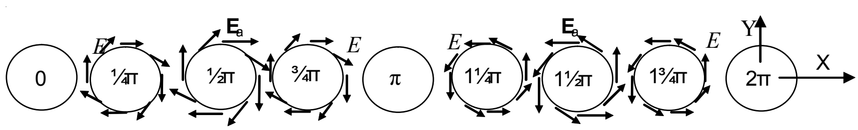

Fig. 6.4. Stages of circulation of the vector of the strength **E** of the electrical field in the photon rotor.

$$\mathbf{E} = \mathbf{E}_a \sin 2\pi\nu t = \mathbf{E}_a \sin\left(\frac{2\pi}{T}t\right) \tag{6.60}$$

The sinusoidal function (6.60) makes it possible to 'fix' the initial observation conditions within the limits of the period T where the moment of time $t = 0$ corresponds to the zero strength of the field $\mathbf{E} = 0$. With unfolding of the period, the value of the vector $\mathbf{E}$ increases and at time $t = 1/4\ T$ reaches the maximum value $\mathbf{E}_a$ in the stage $1/2\pi$ (the angular phase of oscillations in radians). Subsequently, strength $\mathbf{E}$ starts to decrease and at time $t = 1/2\ T$ in stage π decreases to 0. Further, the direction of circulation of the instantaneous vector of strength $\mathbf{E}$ changes to the opposite direction and passes gradually through all stages in accordance with the harmonic law (6.60) synchronously at every point of the proton.

It should be noted that the direction of circulation of the vector of strength $\mathbf{E}$ in the photon rotor and the direction of the vector $\mathbf{E}$ in the rectangular coordinate system may differ. The circulation of vector $\mathbf{E}$ (6.6) determines the actual state of the photon and the projections of the vector $\mathbf{E}$ of the axes X and Y leave an electromagnetic trace of the photon in the quantised medium which can be recorded by a stationary observer. The projection of $\mathbf{E}$ on the Y axis gives the transverse component of the vector $\mathbf{E}_y$, and on the X axis it gives its longitudinal components $\mathbf{E}_x$

$$\begin{gathered}\mathbf{E} = \mathbf{E}_y + \mathbf{E}_x \\ E = \sqrt{E_y^2 + E_x^2}\end{gathered} \tag{6.61}$$

Identical stages can also be described for the instantaneous vector of the circulation of strength $\mathbf{H}$ (6.11) of the magnetic field in the photon rotor only in accordance with the sinusoidal law, like the vector $\mathbf{E}$ (6.60). The vectors $\mathbf{E}$ and $\mathbf{H}$ circulate in the anti-phase in the orthogonal polarisation planes $X0Y$ and $X0Z$, and the projections of vector $\mathbf{H}$ on the axes X and Z are denoted by $\mathbf{H}_x$ (longitudinal) and $\mathbf{H}_z$ (transverse), respectively.

In order to investigate the electromagnetic trace of the photon in the quantised medium and describe it mathematically, it is necessary to turn to the special theory of relativity as the theory of relative measurements. Evidently, the described stages of circulation of the electrical and magnetic fields of the photon rotors are real stages in the quantised medium and can be controlled by the observer moving together with the photon at the speed of light C_0. For a stationary observer, all the longitudinal components $\mathbf{E}_x$ and $\mathbf{H}_x$ of the vectors $\mathbf{E}$ and $\mathbf{H}$ become invisible at the photon speed $v = C_0$ [8] because of their relativistic 'shortening'

$$\begin{cases} E_x = (E\cos\alpha_x)\sqrt{1-\dfrac{v^2}{C_0^2}} = 0 \\ H_x = (H\cos\alpha_x)\sqrt{1-\dfrac{v^2}{C_0^2}} = 0 \end{cases} \tag{6.62}$$

Here α_x is the angle of inclination of the vectors **E** and **H** to the X axis.

Angle α_x in (6.62) is identical for the vectors **E** and **H** with the same coordinate x of application to the rotor because in this case the variation of these vectors in the photon rotor takes place simultaneously (synchronously) as regards both direction and magnitude.

Attention should be given to the fact that the assumptions of the special theory of relativity must be applied with considerable care and only in cases in which we understand the physical nature of the processes associated with the application of relative measurements, although hypothetical, but still measurements, and even more so when measurements are actually taken. For example, in the experiments carried out by Michaelson and Morley no relative measurements across and along the direction of movement of the earth could be made because of the spherical invariance on the whole of the measurement system which travelled together with the observers.

It is important not to confuse the actual processes with errors generated by measurements in the relativistic region. The special theory of relativity has two directions: description of the fundamental relationships and measurement theory. An increase of the relativistic mass of the particles is the fundamental assumption of the relativity theory which occurs in nature regardless of the efficiency of the measurement method. The Lorentz shortening in the direction of motion is the result of measurements, determined by the natural error, especially in the relativistic region, with the errors caused by the finite speed of travel of the measurement signal. For this reason, in (6.62) it is not necessary to use the normalised relativistic factor γ_n (6.3).

The photon as a reference system for the speed of light C_0 is a very interesting object for theoretical physicist. The photon has no mass, i.e., it is not capable of spherical deformation of the quantised medium which generates mass. The photon only transfers the two-rotor polarisation of the quantised medium with the speed of light C_0 in the direction of its movement. The polarisation structure of the photon determines the nature of the photon which corresponds only to the dynamics of movement and excludes the rest state. This leads to the wave electromagnetic processes of movement of the photon in the quantised medium whose two-rotor structure makes it possible to localise the wave in a corpuscule, some bunch of the electromagnetic energy of polarisation of the medium without its spherical deformation. This concept of the photon removes all the contradictions determined by the corpuscular–wave dualism in which the classic mechanics excludes the mutual merger of the wave and the particle in a single object.

However, for the two-rotor structure of the photon to be capable of movement in the quantised medium with the speed of light C_0, it is necessary to examine the relationship to the speed of light C_0 as the speed restricting only the wave process in the quantised medium in the direction of movement of the wave along a straight line. Theoretical physics has been looking closely at supraluminal speeds for a long time, analysing the possibility of supraluminal movement by hypothetical particles, i.e., tachions [10]. If the supraluminal tachion is not regarded as a separate independent particle and is treated as the localised part of the photon rotor, the possibility of the existence of such special formations is quite high.

Every localised part of the photon rotor moves in the straight direction along the X axis with the speed of light C_0 (Fig. 6.2). If the polarisation planes of the photon rotate with the cyclic frequency ω_x, then every point of the rotor describes a helical trajectory in the direction of movement. The length of the helical trajectory increases with the increase of the distance along the straight line in the direction of the X axis around which the helical line is described. Correspondingly, the speed C_0 of any point of the rotor along the helical line will be greater than the speed of light C_0 along a straight line

$$C_c = \sqrt{C_0^2 + v_\tau^2} = C_0\sqrt{1 + \frac{v_\tau^2}{C_0^2}} = C_0\sqrt{1 + \frac{(r_x\omega_x)^2}{C_0^2}} > C_0 \qquad (6.63)$$

where ν_τ is the tangential component of speed along the helical line, m/s; r_x is the distance of the point to the X axis, m.

Equation (6.63) shows that the speed of light C_0 can be reached only in the presence of supraluminal speeds C_c. This is especially relevant in analysis of the speed C_ψ of flux linkage of the field in the photon rotor. Actually, for the rotor of a photon to retain its circular form and for the photon itself to be spherical in rotation of the polarisation planes, the flux linkage of the rotor should also be maintained when the photon travel at the speed of light C_0. This is possible only if the speed C_ψ of flux linkage of the field in the photon rotor is greater than the speed of light C_0. We can determine the minimum speed C_ψ of flux linkage for example for a half-wave model of a photon, assuming that in displacement of the photon by 0.5λ with the speed of light, the speed C_ψ should ensure the closing of the flux around the circle of the mean line $0.5\pi\lambda$ (Fig. 6.2). This is possible if the speed of flux linkage is at least π times greater than the speed of light, i.e.

$$C_\Psi \geq \pi C_0 \tag{6.64}$$

Flux linkage Ω_E or Ω_H determines the fluxes of the electrical Ψ_E or magnetic Ψ_H fields, respectively, along the entire length ℓ of the homogeneous tube of the photon rotor

$$\begin{cases} \Omega_E = \Psi_E \ell = \ell \int\limits_S E dS = ES\ell = \varphi_e S \\ \Omega_H = \Psi_H \ell = \ell \int\limits_S H dS = HS\ell = \varphi_g S \end{cases} \tag{6.65}$$

It can be assumed that every point of the photon rotor moves in a straight line with the speed of light, polarising the quantised medium by wave perturbation. In this case, the quantons at every point of the rotor link together synchronously, ensuring that the flux linkage (6.65) is maintained. This flux linkage may not formally be connected with the determined speed C_ψ (6.64). However, in this case, the other speed C_ψ of flux linkage should be many times greater than the speed of light because the process of flux linkage in the rotor should take place in the period not shorter than the duration of relaxation of the quanton which is of the order of $T_0 = 2.5 \cdot 10^{-34}$ s [1]. In this case, we can estimate approximately the speed C_ψ of flux linkage for the half wave model of the photon with $\lambda = 0.63 \cdot 10^{-6}$ m (Fig. 6.2)

$$C_\Psi = \frac{2\pi r_\lambda}{T_0} = \frac{\pi\lambda}{T_0} = 8 \cdot 10^{29}\,\mathrm{m/s} = 2.7 \cdot 10^{21} C_0 \tag{6.66}$$

Even higher speeds C_ψ of flux linkage should be found in the classic spherical electromagnetic wave where the radius r_γ of the sphere of the wave increases with the speed of light in moving away from the radiation source, ensuring the formation of electrical and magnetic rotors of the wave (Fig. 6.1). It may be also suggested that these high speeds, such as (6.66) or higher, are the results of only mathematical calculations and the actual situation is linked with the synchronous relaxation of quantons. However, the flux linkage in the rotor is also a reality, and the problem of the speed of flux linkage should be solved because flux linkage ensures the stability of the rotors in the electromagnetic wave. It is possible that the speed C_ψ of flux linkage in the rotor is rather a energy information problem in which the information according to which the process has started travels through all the quantons in the photon rotor with the speed (6.66).

It is sufficient to break up rotors at the photon and the photon is immediately destructed transferring its energy to, for example, an atom in photon absorption. Naturally, the process of transfer of energy from the photon to the atom takes place through an orbital electron when the breaking of the photon rotors increases the strength of the electrical and magnetic fields of the electron–nucleus system, ejecting the electron to a higher orbit. This means that the electron must be moved away from the nucleus of the atom to the region of the quantised medium which does not restrict the electron mass, as in the vicinity of the nucleus with the relativistic electron. Consequently, the electron can restore its mass to the initial condition which was reduced as a result of the mass defect during emission of the photon. In this case, the electron–nucleus system operates as a receiving resonance antenna on the microscopic level. For this reason, the absorption spectra of the atoms differ from the radiation spectra, because they are produced by different mechanisms.

Therefore, to ensure stability of the photon, it is necessary to ensure the stability of the rotors by circulation of the vectors **E** and **H** as a result of the exchange of electrical and magnetic energies between the rotors of the quantised medium through the diagonal points *a* and *b* (Fig. 6.2). In particular, as a result of reactive (without losses) electromagnetic exchange of the photon energy with the quantised medium, the medium retains the electromagnetic wave trace.

The presence of diagonal points *a* and *b* and, more accurately, local regions of energy exchange in the photon rotors, gives the specific physical meaning to the speed C_ψ of flux linkage (6.66). In a general case in which it is necessary to determine the speed, it is essential to specify the initial coordinates from which counting is started in the propagation of the process to determine its initial speed. For the speed of flux linkage C_ψ (6.66), the initial coordinates are the diagonal points *a* and *b* of the photon rotors. These points indicate the start of dynamics of the process linking together the electrical and magnetic components of the photon through its rotors into a general electromagnetic field.

The EQM theory and the Superunification theory present the most powerful analytical apparatus of theoretical physics enabling investigations to be extended to the level of the diameter of the quantum of the order of 10^{-25} m, into the zones of the local regions of energy exchange in the photon rotors, indicated by the diagonal points *a* and *b* in Fig. 6.2 and 6.3. The state of the quanton as a result of its electromagnetic polarisation was analysed in [1] when deriving Maxwell equations. It was established that the electrical energy of the quanton can increase only as a result of reducing its magnetic energy ensuring the energy balance of the quanton and, at the same time, determining the action of the laws of electromagnetic induction in vacuum. Electricity can interact with magnetism only through a quanton, or vice versa.

Now, by analogy with [1], it is necessary to examine the mechanism linking together the electrical and magnetic rotors of the photon leading to wave energy exchange with the quantised medium. For this purpose, it is sufficient to analyse the processes, linking together two lines of force: electrical and magnetic in the photon rotors, which in the EQM theory are represented by a string of quantons closed around a ring.

Figure 6.5 shows the diagram of connection of the electrical and magnetic rotors of the photon through the quantons at the diagonal zones (points) a and b. In this case, the rotors of the vectors **E** and **H** consist of a set of quantons are oriented with the electrical axis in the direction of vector **E** and with the magnetic axis in the direction of vector **H**, forming strings of tensions closed around a circle. The mean statistical angle of orientation of the axes of the quantons and the displacement of the charges inside the quanton from the equilibrium state are determined the direction and magnitude of the vectors **E** and **H** in the rotors [1]. In order to avoid complicating the scheme, Fig. 6.5 shows only the connecting quantons in the diagonal points a and b of intersection of the rotors. The quantons are denoted in the projection on the plane by four monopole charges: two electrical ones (e^+ and e^-) and two magnetic ones (g^+ and g^-) connected into the electrical and magnetic dipoles, whose axes are always orthogonal.

It is pleasing to see that every electromagnetic process analysed using quantons as test particles shows its nature to the observer without any contradictions, explaining the reasons for the very phenomenon. In this case, this relates to the formation and behaviour of the rotors at the speed of light which form electromagnetic fields and the structure of the photon. In the electrodynamics, the state of fields is analysed by the method of test

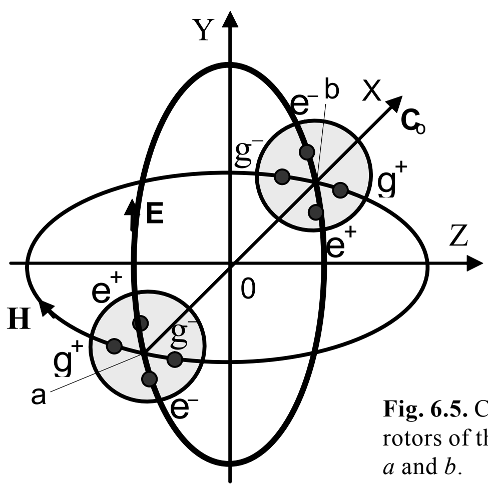

Fig. 6.5. Connection of the electrical and magnetic rotors of the photon through quantons at the points *a* and *b*.

particles-charges. The EQM theory offers for the first time a method in which the test particle is represented by a quanton, with the distinguishing feature being that the quanton combines in itself the orthogonal system of fields.

This approach in mathematics has resulted in the development of a very powerful theory of the functions of the complex variable limited at the present time to the calculations of plane-parallel orthogonal fields. However, the mathematical theory offers new calculation methods, whereas the physical theory is directed to explaining the nature of the phenomenon. In the past physics was referred to as natural philosophy for good reason. Analysing the electromagnetic fields by the method of the test quanton, we can understand the nature of the phenomenon and in cases in which it is necessary to carry out calculations there are no significant difficulties because the calculations are based on the explained physical model. However, the quanton is not only the test particle for analysis but it is also the particle representing the real quantum of the space-time.

Only through the quanton which combines electricity and magnetism, can we link the circulation of electrical and magnetic energies in the photon rotors by synchronous interaction. It should be mentioned that the strength of electrical **E** and magnetic **H** fields of the electromagnetic wave is determined by the displacement of the electrical and magnetic charges inside the quanton by the values Δx and Δy, respectively [1]. For a photon, the displacement of the charges in the rotors should be investigated along the circular line ℓ of the string (the lines of force of the proton), denoting displacement as $\mathbf{\Delta\ell}$ (here $\mathbf{1}_\ell$ is the unit vector of circulation around the circumference ℓ of the proton):

$$\mathbf{E} = \frac{2ek_3\mathbf{1}_\ell}{\varepsilon_0 L_{q0}^3}\Delta\ell \tag{6.67}$$

$$\mathbf{H} = \frac{2gk_3\mathbf{1}_\ell}{L_{q0}^3}(-\Delta\ell) \tag{6.68}$$

here $L_{q0} = 0.74\cdot10^{-25}$ m is the quanton diameter, $k_3 = 1.44$ is the filling factor [1].

For the connecting quantons in the zones a and b in Fig. 6.5, the vectors **E** (6.67) and **H** (6.68) are initially orthogonal with respect to the condition of their application to the quanton. The positive displacement of the electrical charges $\Delta\ell$ is associated with the tensioning of the electrical axis of the quanton, whereas the negative displacement ($-\Delta\ell$) determines the anti-phase compression of the magnetic axis. We can determine the displacement of the charges in the photon rotors, for example, for λ= 637 nm, because the parameters of the field $E = 0.516\cdot10^{12}$ V/m and $H = 1.37\cdot10^{9}$ A/m are available (Table 6.2)

$$\Delta\ell = \frac{\varepsilon_0 L_{q0}^3}{2ek_3}E = 4.01\cdot10^{-57}\,\text{m} \tag{6.69}$$

$$-\Delta\ell = \frac{L_{q0}^3}{2gk_3}H = 4.01\cdot10^{-57}\,\text{m} \tag{6.70}$$

As indicated by (6.69) and (6.70), the EQM theory gives the same displacement of electrical and magnetic charges of the quantons in the rotors of the photon, determining the synchronous displacement of the charges in the anti-phase. The displacement of the charges of the order of 10^{-57} m for $\lambda = 637$ nm is extremely small in relation to the diameter of the quanton of the order of 10^{-25} m. Regardless of such a small displacement of the charges, the disruption of the electrical and magnetic equilibrium of the quantised medium in the photon rotors is determined by the relatively high parameters of the strength of the fields $E = 0.516\cdot10^{12}$ V/m and $H = 1.37\cdot10^{9}$ A/m (Table 6.2). This again stresses that the quantised medium is characterised by colossal elasticity resulting in the relatively high speed $C_0 \sim 3\cdot10^{8}$ m/s of propagation of the wave processes in this medium.

Previously, it was shown that the rotors of the electrical and magnetic fields of the photon are situated in the orthogonal polarisation planes and the intersection of these planes determines the direction of movement of the photon represented by the vector of speed C_0 on the X axis (Fig. 6.2). This is determined by the fact that initially the electromagnetic field of the photon forms as a spherical wave but this takes place at speed C very close to the speed of light C_0. Therefore, in the photon there is a short time period (6.59) essential for expanding the photon to the finite size, determined by the wavelength. Reaching the speed of light, the photon cannot expand any further, fixing its wave (half-wave) diameter and stabilising the frequency of circulation of the electrical and magnetic energies in the photon rotors.

Circulation of the electrical and magnetic energies in the rotors of the photon and synchronisation of circulation take place as a result of the work of connecting quantons in the zones a and b (Fig. 6.5). In fact, the displacement $\boldsymbol{\Delta\ell}$ (6.69) of the electrical charges in the connecting quanton in the zone a along the chain consisting of photons causes displacement by $\Delta\ell$ of the charges in all quantons of the circular string of the electrical rotors. This displacement of the electrical charges determines the strength $\mathbf{E}$ (6.67) of circulation of the electrical field in the photon rotor, leading to flux linkage (6.65) of the quantons of the rotor.

Displacement $\mathbf{\Delta}\ell$ (6.69) of the electrical charges in the connecting quanton (zone *a*) is connected synchronously with the displacement ($-\mathbf{\Delta}\ell$) (6.70) in the anti-phase of the magnetic charges of the quanton. As shown in [1], this is determined by the law of energy conservation which also holds for the quanton as a carrier of the electromagnetic wave. The displacement of the magnetic charges determines the strength **H** (6.68) of circulation of the magnetic field in the photon rotor synchronously with the circulation of vector **E**. Identical processes take place in the second connecting quanton in the zone *b*. In fact, the two-rotor structure of the quanton represents a microscopic electromagnetic oscillatory circuit moving in the quantised medium with the speed of light.

Thus, the interaction between electricity and magnetism inside the photon, resulting in the circulation of the field and of electromagnetic energy in the photon rotors, takes place through the connecting quantons in the zones *a* and *b*. Therefore, we examine in greater detail the processes of circulation of electrical and magnetic energy in the electrical and magnetic rotors of the photon as in an oscillatory circuit. For this purpose, the total energy $\hbar\nu$ of the photon is represented by its electrical W_e and magnetic W_g components which are equivalent to each other:

$$W = \hbar\nu = W_e + W_g = \frac{1}{2}\int_V \varepsilon_0 E^2 dV + \frac{1}{2}\int_V \mu_0 H^2 dV \tag{6.71}$$

It should be mentioned that the equivalence of electricity and magnetism in the electromagnetic wave, not disregarding the photon, is determined by the ratio E/H as an exact constant, regardless of the values of E and H, and determines the wave resistance of the quantised medium of 377 ohm

$$\frac{E}{H} = \frac{1}{\varepsilon_0 C_0} = \mu_0 C_0 = 377\frac{\text{V}}{\text{A}} = 377 \text{ ohm} \tag{6.72}$$

For a proton with a homogeneous cross-section and constant volume $V = S_{ef}\ell$ with the mean length ℓ (6.41) of the lines of force in the rotor taken into account, the expression (6.71) is simplified

$$V = S_{ef}\ell = \frac{\pi}{2}S_{ef}\lambda \tag{6.73}$$

$$W = \hbar\nu = \frac{1}{2}\varepsilon_0 E^2 V + \frac{1}{2}\mu_0 H^2 V \tag{6.74}$$

Equation (6.74) determines the balance of electrical and magnetic energies for the actual values of the strength E and H. In transition to instantaneous values represented by the cosine function (6.12), the instantaneous value of energy W_{in} of the photon changes in the proton with the doubled cyclic frequency 2ω, where ω = 2πν

$$W_{in} = \frac{1}{4}\varepsilon_0 VE_a^2[1+\cos(2\omega t)] + \frac{1}{4}\mu_0 VH_a^2[1+\cos(-2\omega t)] \qquad (6.75)$$

Equation (6.75) includes the components of the energy which characterise its specific level W_{const} in relation to which the variable component of energy W_{var} in the photon rotors circulates

$$W_{const} = \frac{1}{4}\varepsilon_0 VE_a^2 + \frac{1}{4}\mu_0 VH_a^2 \qquad (6.76)$$

$$W_{\mathrm{var}} = \frac{1}{4}\varepsilon_0 VE_a^2 \cos(2\omega t) - \frac{1}{4}\mu_0 VH_a^2 \cos(2\omega t) \qquad (6.77)$$

Equations (6.76) and (6.77) can be reduced to the form (6.74), replacing the amplitude values E_a and H_a by the actual values $E_a = \sqrt{2}\cdot E$ and $H_a = \sqrt{2}\cdot H$ and taking into account that for the actual values cos(2ωt) = 1, as in the case of the effect of the static field is

$$W_{\mathrm{const}} = \frac{1}{2}\varepsilon_0 VE^2 + \frac{1}{2}\mu_0 VH^2 = \hbar\nu \qquad (6.78)$$

$$W_{\mathrm{var}} = \frac{1}{2}\varepsilon_0 VE^2 - \frac{1}{2}\mu_0 VH^2 = \frac{1}{2}\hbar\nu - \frac{1}{2}\hbar\nu = 0 \qquad (6.79)$$

Equation (6.79) can be derived as a mean quadratic equation, integrating the square (6.77) in the interval of the period, separating the results by the period and calculating the square root. Further, we write the actual value of energy as the sum of (6.78) and (6.79)

$$W = W_{\mathrm{const}} + W_{\mathrm{var}} = \hbar\nu + \left(\frac{1}{2}\varepsilon_0 VE^2 - \frac{1}{2}\mu_0 VH^2\right) = \hbar\nu \qquad (6.80)$$

As indicated by (6.80), the energy of the photon, determined as a result of renormalisation of energy is equivalent to the photon energy (6.74). However, the physical meaning of energy (6.8) differs completely from that of energy (6.74). The form of the equation (6.74) reflects the classic approach to the problem of photon energy assuming that the energy, transferred by the photon, is accumulated only in the photon rotors. However, in the classic approach, when rejecting the light-bearing quantised medium, expression (6.74) does not reflect the circulation of the energy when the electrical energy of the photon should be completely converted to its magnetic energy, and vice versa. It may easily be shown that this is possible only if there is a phase shift of $\pi/2$ between the vectors **E** and **H**. In fact, there is no phase shift in the electromagnetic wave. The vectors **E** and (–**H**) can exist only simultaneously and in the anti-phase. This shows convincingly that the classic approach contains contradictions which are eliminated by the equation (6.80).

In particular, expression (6.74) does not reflect the fact that the energy in the photon rotors circulates in the anti-phase in relation to the sign of the energy. This may be explained as follows. If the energy in the electrical rotors is positive, then at this moment the energy in the magnetic rotor is negative. Conversely, at the moment when the energy in the electrical rotor is negative, the sign of the energy in the magnetic rotor changes to positive. The sign of the energy determines its direction: positive value of the energy is associated with extraction of the energy from the quantised medium, the negative value with the absorption by the quantised medium. This is reflected in (6.77) and (6.80).

The equations (6.77) and (6.80) reflect the actual position of the photon, and the wave displacement of the photon in the quantised medium with the speed of light is possible only as a result of the exchange of electromagnetic energy of the photon with the quantised medium. The photon cannot exist without the light-bearing medium. For the classic equation (6.74) to be valid, the equation should realise the concept of circulation of the energy between the electrical and magnetic rotors of the photon. However, as shown by analysis, there is no such mechanism of circulation of energy in nature. The photon energy can circulate only as a result of exchange of energy with the quantised medium in accordance with (6.77) and (6.80), when the positive energy of the electrical rotor is connected with the extraction of the energy from the quantised medium, whereas the negative energy of the magnetic rotor is directed to transfer to the quantised medium, and vice verse. The photon is capable of leaving a wave electromagnetic trace in the quantised medium (showing the wave properties) only as a result of energy exchange with the quantised medium.

Actually, in the formation of the photon as a result of the mass defect of the orbital electron energy $\hbar\nu$ being a constant is immediately released into the quantised medium because the mass defect is a constant value with time. However, this energy can be transferred in space only as a result of a wave process. Therefore, the energy of the mass defect as the energy of the elastic deformation of the medium is released and causes a wave process to take place leading to the formation of two rotors. The energy is divided equally between these rotors (6.74) and each half circulates in the rotors of the photon in accordance with (6.77). However, expression (6.74) does not take into account the sign of the energy, like equation (6.80).

Equation (6.74) was written on the basis of the formal energy balance. In more detailed analysis by taking into account the sign of the argument ($-2\omega t$) in (6.75) which considers the anti-phase circulation of energy it is possible to determine more accurately the energy balance (6.80) of the photon in the quantised medium. The energy balance of the photon (6.80) determines the continuous exchange of energy with the quantised medium. The amount of energy, directed from the quantised medium to one of the rotors of the photon, is equivalent to the amount of energy ejected by another rotor into the quantised medium, maintaining the initial energy $\hbar\nu = \Delta m_e C_0^2$ of the photon constant.

On the level of the quantons this is reflected in the fact that when the electrical charges in the electrical rotor inside the quantons travel away from each other, the magnetic charges in the magnetic rotor inside the quanton come closer together, and vice versa. The movement of the charges away from each other in the quantons is equivalent to a decrease of their internal energy and an increase of the external energy in the medium in the photon rotor, and vice versa. In movement of the photon, the rotor runs on the quantised medium resulting in its polarisation. At the same time, the quanton leaves the medium, releasing polarisation energy. This is possible only in the case of continuous exchange of energy between the rotors of the photon and the quantised medium leading to the wave transfer of the photon in the medium with the speed of light.

As already mentioned, as a result of relativistic shortening of the longitudinal components $\mathbf{E}_x$ and $\mathbf{H}_x$ (6.62) of the electromagnetic wave recorded by a stationary observer, it is important to examine oscillations of all the transverse components of the instantaneous vectors of the strength $\mathbf{E}_y$ and $\mathbf{H}_z$ (6.61) along the axes Y and Z, respectively, where α_x is the angle of inclination of the vectors $\mathbf{E}$ and $\mathbf{H}$ to the X axis

$$\begin{cases} \mathbf{E}_y = \mathbf{E}\cos\alpha_x \\ \mathbf{H}_z = -\mathbf{H}\cos\alpha_x \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.81}$$

System (6.81) links the application of the vectors $\mathbf{E}$ and $\mathbf{H}$ on the photon rotor with the same coordinate x.

Figure 6.6 shows the transverse projections of the instantaneous vector of strength $\mathbf{E}_y$ of circulation of the rotors of the electrical field of the photon on the Y axis (a), and shown separately inside the rotor (b). The maximum value of the transverse components of the strength vector is obtained at the diametral points a and b, and change to the zero state in the centre of the photon on the Y axis, changing in accordance with the law (6.81). The

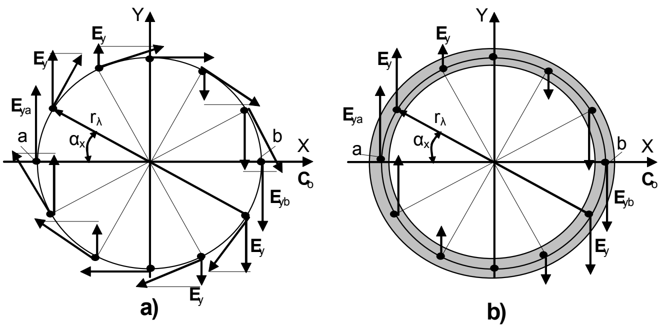

Fig. 6.6. Construction of transverse projections on the *Y* axis of the instantaneous vector of strength E_y of circulation of the rotor of the electrical field of the photon (a) and definition of transverse projections inside the cross-section of the rotor (b).

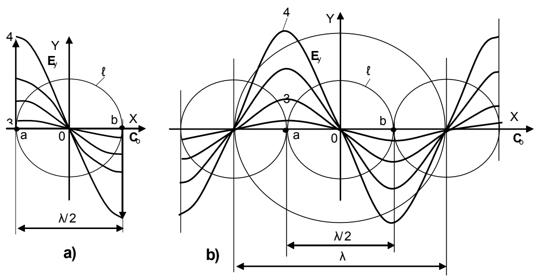

Fig. 6.7. Variation of the transverse component E_y inside the photon in the half wave (a) and wave (b) models.

identical pattern of the fields may also be visualised for the vector of circulation of the instantaneous values of the transverse component of the strength $\mathbf{H}_z$ (6.81) of the magnetic field of the photon rotor, taking into account the orthogonality of the vectors $\mathbf{H}_z$ and $\mathbf{E}_y$.

Figure 6.7 shows the graphs of the variation of the transverse component of the strength $\mathbf{E}_y$ of the electrical field inside the photon for the half- wave (a) and wave (b) models. Similar graphs can also be constructed for the variation of the transverse component of the strength $\mathbf{H}_z$ (6.81) of the magnetic field inside the photon rotor. The half-wave model (a) can be characterised, as already mentioned, only by a specific stage in the development of the wave model (b). These graphs show that the half-wave model does not satisfy the wave equation of the photon in the total volume when the wave should be described as changing with both time and in space. Therefore, prior to further analysis, it is necessary to show how the wave equation of the photon is derived.

6.4. The wave equation of the photon

In [1], a relatively simple method of derivation of the wave equation of classic electromagnetic wave on the basis of analysis of the displacement of the electrical and magnetic charges inside quantons in the passage of the electromagnetic wave through the quantised medium has already been described. The method can also be used for deriving the wave equation of the photon. However, in the EQM theory, it is possible to propose a new method of deriving the wave equation of the photon. For this purpose, we compare the equations (6.81) and (6.11), presenting (6.81) in the following form:

$$\begin{cases} \mathbf{E} = \mathbf{E}_a \cos\left(\dfrac{2\pi}{T}t\right) \\ \mathbf{H} = \mathbf{H}_a \cos\left(-\dfrac{2\pi}{T}t\right) \end{cases} \qquad \mathbf{E} \perp \mathbf{H} \tag{6.82}$$

The equation (6.82) reflects the variation of the vectors **E** and **H** with time t in accordance with the cosine law, and the increase of these vectors with time is indicated by individual stages in the graphs 1, 2, 3, 4 (Fig. 6.7). The graphs 1, 2, 3, 4 reflect the distribution in space of the transverse components of the strength $\mathbf{E}_y$ and $\mathbf{H}_y$ also in accordance with the cosine law (6.81). For this purpose, the argument α_x of function (6.81) is expressed through the linear parameters of the photon, linking the angle α_x with wavelength λ and the coordinate x through the appropriate increments, where ℓ is the length of the mean line of the photon rotor with a radius r_λ:

$$d\alpha_x = \frac{d\ell}{r_\lambda} = 2\pi\frac{d\ell}{\ell} \tag{6.83}$$

In equation (6.83), the relationship between the small angle $d\alpha_x$ and the variation $d\ell$ is connected with the fact that in the range of small angles $\sin(d\alpha_x) \approx d\alpha_x$, and we obtain $d\ell = r_\lambda \sin(d\alpha_x) \approx r_\lambda d\alpha_x$ (Fig. 6.7). Evidently, the angle α_x with the photon travelling the distance equal to the wavelength λ should carry out the complete rotation 2π. Consequently, for the amplitude of the transverse components $\mathbf{E}_{ay}$ and $\mathbf{H}_{az}$ the variation of the coordinates dx in the direction of movement of the wave and the increment $d\ell$ can be connected by the proportion:

$$\frac{dx}{\lambda} = \frac{d\ell}{\ell} \tag{6.84}$$

Substituting (6.84) into (6.83) and integration gives

$$\alpha_x = 2\pi \frac{x}{\lambda} \tag{6.85}$$

Thus, the wave properties of the photon should satisfy the condition (6.85), with the value of x varying from 0 to λ. We substitute (6.85) into (6.81) and obtain the linear distribution of the transverse component of the strength $\mathbf{E}_y$ and $\mathbf{H}_y$ of the fields along the wavelength in the form of a cosine function through the transverse amplitudes $\mathbf{E}_{ay}$ and $\mathbf{H}_{az}$

$$\begin{cases} \mathbf{E}_y = \mathbf{E}_{ay} \cos\left(\dfrac{2\pi}{\lambda} x\right) \\ \mathbf{H}_z = -\mathbf{H}_{az} \cos\left(\dfrac{2\pi}{\lambda} x\right) \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.86}$$

Equation (6.86) determines the linear distribution of the transverse component of the strength of the field $\mathbf{E}_y$ and $\mathbf{H}_z$ along the wavelength. Equation (6.82), which describes the time distribution of the vectors $\mathbf{E}$ and $\mathbf{H}$ will also hold for the transverse components of the strength of the field $\mathbf{E}_y$ and $\mathbf{H}_z$

$$\begin{cases} \mathbf{E}_y = \mathbf{E}_{ay} \cos\left(\dfrac{2\pi}{T} t\right) \\ \mathbf{H}_z = -\mathbf{H}_{az} \cos\left(\dfrac{2\pi}{T} t\right) \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.87}$$

The equations (6.86) and (6.87) link the variation of the transverse components of the strength of the field $\mathbf{E}_y$ and $\mathbf{H}_y$ in time t and in space along the wavelength λ. To connect the components $\mathbf{E}_y$ and $\mathbf{H}_y$ by a wave equation, we determine the partial derivatives with respect to time t from (6.86) and along the length x from (6.87)

$$\begin{cases} \dfrac{\partial \mathbf{E}_y}{\partial x} = -\dfrac{2\pi}{\lambda} \mathbf{E}_{ay} \sin\left(\dfrac{2\pi}{\lambda} x\right) \\ \dfrac{\partial \mathbf{H}_z}{\partial x} = \dfrac{2\pi}{\lambda} \mathbf{H}_{az} \sin\left(\dfrac{2\pi}{\lambda} x\right) \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.88}$$

$$\begin{cases} \dfrac{\partial \mathbf{E}_y}{\partial t} = -\dfrac{2\pi}{T} \mathbf{E}_{ay} \sin\left(\dfrac{2\pi}{T} t\right) \\ \dfrac{\partial \mathbf{H}_z}{\partial t} = \dfrac{2\pi}{T} \mathbf{H}_{az} \sin\left(\dfrac{2\pi}{T} t\right) \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.89}$$

Taking into account that the wavelength λ and the period T are connected, and also that the distance x and time t are connected for the wave front together through the speed of light ($\lambda = C_0 T$ and $x = C_0 t$), the linear equation (6.18) will be reduced to the temporary form

$$\begin{cases} C_0 \dfrac{\partial \mathbf{E}_y}{\partial x} = -\dfrac{2\pi}{T}\mathbf{E}_{ay}\sin\left(\dfrac{2\pi}{T}t\right) \\ C_0 \dfrac{\partial \mathbf{H}_z}{\partial x} = \dfrac{2\pi}{T}\mathbf{H}_{az}\sin\left(\dfrac{2\pi}{T}t\right) \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.90}$$

We equate the left-hand part of (6.89) and (6.19) because their right-hand parts are equal, and obtain the wave equation of the photon

$$\begin{cases} \dfrac{\partial \mathbf{E}_y}{\partial t} = C_0 \dfrac{\partial \mathbf{E}_y}{\partial x} \\ \dfrac{\partial \mathbf{H}_z}{\partial t} = C_0 \dfrac{\partial \mathbf{H}_z}{\partial x} \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.91}$$

Increasing the order of partial derivatives, we reduce the wave equation (6.91) of the photon to the differential equation of the second order in partial derivatives in the classic form:

$$\begin{cases} \dfrac{\partial^2 \mathbf{E}_y}{\partial t^2} = C_0^2 \dfrac{\partial^2 \mathbf{E}_y}{\partial x^2} \\ \dfrac{\partial^2 \mathbf{H}_z}{\partial t^2} = C_0^2 \dfrac{\partial^2 \mathbf{H}_z}{\partial x^2} \end{cases} \quad \mathbf{E}_y \perp \mathbf{H}_z \tag{6.92}$$

At the same time, the wave equation (6.92) of the electromagnetic wave of the photon differs from the classic equation by the fact that it contains only transverse components of the strength of the field $\mathbf{E}_y$ and $\mathbf{H}_z$. The longitudinal components $\mathbf{E}_x$ and $\mathbf{H}_x$ (6.62) of the field remain unobserved because of their relativistic shortening. The longitudinal components of the electromagnetic field are not found in the classic electromagnetic wave.

Because of the relativistic shortening of the longitudinal components of the field these differences between the wave equations (6.91) and (6.92) of the photon cause differences in comparison with the Maxwell equations (6.10) to which the strength (6.61) of the transverse components $\mathbf{E}_y$ and $\mathbf{H}_z$ of the field corresponds only at the diagonal points a and b of the photon rotor. In this case, the longitudinal component $\mathbf{E}_x = 0$ and $\mathbf{H}_x = 0$ is not found in the rotor and there is only the transverse component $\mathbf{E}_y$ and $\mathbf{H}_y$, which determines the density of current in the Maxwell equations

$$\begin{cases} \mathbf{E} = \mathbf{E}_y \\ \mathbf{H} = \mathbf{H}_z \end{cases} \text{ at the points } a \text{ and } b \tag{6.93}$$

Since the longitudinal components of the electromagnetic wave of the photon are also found in reality, the wave equations can also be written through the longitudinal components which replace the transverse components in (6.91) and (6.92). On the whole, the differential equations (6.91) and (6.92) do not change if the transverse components are replaced by their total vectors **E** and **H** in (6.82).

As a result of analysis of the half-wave model of the photon (Fig. 6.7a) we obtain the wave equations (6.91) and (6.92) of the photon which enable the problem of the structure of the photon to be finally solved. Thus, in order to form the wave front of the photon with time and in space the wave process should be organised at least within the limits of the entire period. The half-wave model does not correspond to these conditions, showing the truncation of the leading and trailing fronts of the waves, as shown in Fig. 6.7a.

The wave front can be restored fully only in the wave model (Fig. 6.7b). For this purpose, three half-wave models are combined on the X axis and in the centre we obtain a wave model with the integral wave front, as shown in Fig. 6.3. In order to form the integral wave front, the latter should include the entire region inside the photon rotor along the entire wavelength λ. As already mentioned, this condition is satisfied by disc rotors with an ellipsoidal cross-section which in the case of the low-energy photons in the optical range is extended into a narrow band with the thickness of the order of 10^{-20} m (6.56).

Consequently, we can determine the sinusoidal distribution of the strength **E** and **H** of the field of the rotor in the cross-section of the photon when moving away from its centre 0 to the distance x when the transfer of the start of counting from the point a by $1/4\lambda$ of the cosine function (6.86) along the X axis to point 0 transforms the cosine to the sine

$$\begin{cases} \mathbf{E} = \mathbf{E}_a \sin\left(\dfrac{2\pi}{\lambda} r\right) \\ \mathbf{H} = -\mathbf{H}_a \sin\left(\dfrac{2\pi}{\lambda} r\right) \end{cases} \qquad \mathbf{E} \perp \mathbf{H} \tag{6.94}$$

Equation (6.94) presents the total vectors **E** and **H** and not their transverse components $\mathbf{E}_y$ and $\mathbf{H}_y$ (6.86). This is associated with the fact that, as already mentioned, the transverse components $\mathbf{E}_y$ and $\mathbf{H}_y$ along the X axis are equivalent to the total vectors **E** and **H** of the photon rotor. Taking into account the spherical symmetry of the photon, the actual (without relativistic shortening) distribution of the strength of the field in the photon rotors is determined by the sinusoidal function (6.94) in the appropriate polarisation planes (in the planes of the photon rotors).

In classic electrodynamics it is accepted that the strength of a circular field, for example in the magnetic rotor of linear current, weakens when moving away from the centre of the rotor. For a photon, there is no strength in the centre of the rotor and the strength increases in accordance with the sinusoidal law (6.94), reaching the maximum value at $r = 1/4\lambda$ for the mean radius of the photon r_λ. With further movement away from the centre of the photon, the strength of the field in the rotor decreases to 0 at $r = 1/2\lambda$. Actually, in rotation of the polarisation planes the photon represents a spherical bunch of the energy of the electromagnetic field of polarisation of the quantised medium in the volume of the wave front at the wavelength λ. The photon energy is localised in the volume of the space restricted by the wavelength and the wave front.

Thus, analysing the electromagnetic field of the total wave model of the photon (Fig. 6.7b) it has been established that for a stationary observer the field of the photon is described by the equation (6.87) and the wave equations (6.91) and (6.92). The wave electromagnetic trace is shown graphically in Fig. 6.8. This trace is left by the wave front of the photon moving in space with the speed of light C_0 and the amplitude of the transverse components $\mathbf{E}_{ay}$ and $\mathbf{H}_{az}$. It may be seen that the observed relativistic electromagnetic trace of the photon in the quantised medium does not differ from the classic electromagnetic wave with the transverse oscillations of the vectors of the strength of the electrical and magnetic fields.

Analysis also shows that the half-wave model of the photon, selected for average calculations, was used in the final analysis for justifying the wave model of the photon. The averaged-out parameters of the half-wave model correspond to the actual parameters of the wave model of the photon. Actually, the distribution of the strength of the field according to the sinusoidal law (6.94) makes it possible to determine the actual parameters of the field $\mathbf{E}$ and $\mathbf{H}$ in the range from 0 to $1/2\lambda$. These parameters characterise the RMS values (effective values corresponding to the uniform fields)

$$\begin{cases} E = \sqrt{\dfrac{1}{\lambda/2}\displaystyle\int_0^{\lambda/2} E_a^2 \sin^2\left(\dfrac{2\pi}{\lambda} r\right) dr} = \dfrac{E_a}{\sqrt{2}} \\ H = \sqrt{\dfrac{1}{\lambda/2}\displaystyle\int_0^{\lambda/2} H_a^2 \sin^2\left(\dfrac{2\pi}{\lambda} r\right) dr} = \dfrac{H_a}{\sqrt{2}} \end{cases} \tag{6.95}$$

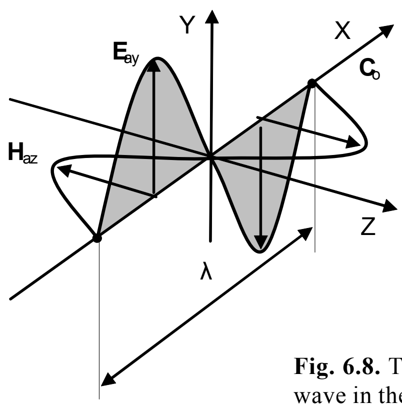

Fig. 6.8. The observed electromagnetic trace of the photon wave in the quantised medium.

Initially, the half-wave model was based on the conclusions (6.95) which treated this model as an averaged-out model, characterised by the RMS parameters of the photon. Averaging was based on the fully substantiated assumptions in which the nonuniform field of the photon rotor is replaced by a uniform field in the cross-section and is equivalent to the nonuniform field as regards efficiently. For transition to the averaged-out model, it is fully justified to use the condition (6.95) which take into account the sinusoidal distribution of the field in the cross-section of the photon rotor. This also relates to the determination of the effective cross-section of the rotor of the photon S_{ef} (6.34).

6.5. Total two-rotor structure of the photon

Now, when the main parameters of the photon are available, it is necessary to improve the accuracy of the configuration of the fields of the photon. This is very important when investigating the interaction of a photon with material media, including optical media. In particular, the interaction of photon fields with local fields of atomic structures on matter determines the slowing down of light C in the matter in comparison with the speed of light C_0 in vacuum (quantised medium). Until now, the reasons for these phenomena were unknown in quantum electrodynamics, like the reasons for the partial carrying away of the light by the moving medium, because analysis of the reasons for these phenomena cannot be carried out without participation of the quantised medium as the light-bearing medium [12].

To construct the total configuration of the electromagnetic field of the photon we use the method of the test quanton and investigate the possible orientation of the magnetic axes in the electrical rotor and orientation of the electrical axes of the quanton in the magnetic field of the photon. In this case, the rotor field of the photon in the polarisation plane should generate a radial field in the same plane. The mechanism of this phenomenon will be investigated later and, at the moment, the radial electrical field is denoted by rad**E**, the magnetic field as rad**H**. We also describe the operation in which the rotor rot**H** of the magnetic field of the photon induces the radial electrical field rad**E**, and the electrical rotor rotE induces the radial magnetic field rad**H**

$$\begin{cases} \operatorname{rad}\mathbf{H} = -\varepsilon_0 C_0 \operatorname{rot}\mathbf{E} \\ \operatorname{rad}\mathbf{E} = -\mu_0 C_0 \operatorname{rot}\mathbf{H} \end{cases} \tag{6.96}$$

In classic electrodynamics, rotor **E** is represented by the partial derivative of the strength **H** of the magnetic field with time, and rotor **H** is the partial derivatives of the strength **E** of the electrical field with time [1]. The theory of the photon as a particle having the complete symmetry between electricity and magnetism enables the possibilities of these functions can be expanded, replacing in rot**E** of the electrical parameters by excellent magnetic parameters, and in rot**H** the magnetic parameters by equivalent electrical parameters

$$\begin{cases} \operatorname{rot}\mathbf{E} = -\mu_0 \dfrac{\partial \mathbf{H}}{\partial t} = \dfrac{1}{C_0}\dfrac{\partial \mathbf{E}}{\partial t} \\ \operatorname{rot}\mathbf{H} = -\varepsilon_0 \dfrac{\partial \mathbf{E}}{\partial t} = \dfrac{1}{C_0}\dfrac{\partial \mathbf{H}}{\partial t} \end{cases} \tag{6.97}$$

Replacing rot**E** and rot**H** in (6.96) from (6.97) we obtain

$$\begin{cases} \operatorname{rad}\mathbf{H} = -\varepsilon_0 \dfrac{\partial \mathbf{E}}{\partial t} \\ \operatorname{rad}\mathbf{E} = -\mu_0 \dfrac{\partial \mathbf{H}}{\partial t} \end{cases} \tag{6.98}$$

Equation (6.98) indicates that the variation of the electrical field **E** with time inside the electrical rotor of the photon results in the interaction of the radial magnetic field **H** in the electrical rotors and, vice versa, the change of the magnetic field **H** with time inside the magnetic rotor results in the induction of the radial electrical field **E** in the magnetic field of the photon. The electrical and magnetic parameters of the radial and rotor fields are connected by the differential relationships (6.97), establishing the equivalence between the electricity and magnetism in the rotors of the photon:

$$\mathbf{H} = \varepsilon_0 C_0 \mathbf{E}, \quad \mathbf{H} \perp \mathbf{E} \tag{6.99}$$

Equation (6.99) is a solution of the system (6.98) which was previously described by the equivalence condition (6.96). The equation (6.19) can be used to determine the strength of the radial electrical and magnetic fields in the photon rotors on the basis of the strength of the fields circulating in the rotors of the appropriate vectors.

Figure 6.9 shows the mechanism of formation of radial fields $\mathbf{E}_{\mathrm{rad}}$ and $\mathbf{H}_{\mathrm{rad}}$ of the rotors of the photon which in contrast to the rotor fields are denoted by the index ($_{\mathrm{rad}}$). The full image of the field is difficult to describe graphically in the three-dimensional image and, therefore, we only show its individual elements for the part of the rotor in the form of a closed string consisting of quantons. The quantons are denoted by their projections and orthogonal electrical and magnetic axes connecting into pairs in dipoles electrical and magnetic charges inside the quanton.

On the *Y* axis inside the electrical rotor **E** we specify the quanton 1 whose electrical axis in the limiting case is oriented, to simplify considerations, completely in the direction of the strength vector **E**. A second quanton 2, which belongs to the second rotor string consisting of quantons, is placed below quanton 1. The electrical axis of the quanton 2 is also oriented in the direction of circulation of the vector **E** of the photon rotor. Evidently, the magnetic charges of the quantons 1 and 2, capable of tapping, unfold??? the magnetic axes in the radial direction, forming a radial magnetic field with the strength $\mathbf{H}_{\mathrm{rad}}$. Thus, the circular vector of the electrical field **E**, circulating in the rotor, generates in the same rotor the radial magnetic field $\mathbf{H}_{\mathrm{rad}}$ in accordance with (6.99) which is slightly weaker in comparison with (6.99) because of its secondary induction nature. This weakening of the induced radial field $\mathbf{H}_{\mathrm{rad}}$ is taken into account by the attenuation coefficient k_{at} which will be determined later:

$$\mathbf{H}_{rad} = k_{at}\varepsilon_0 C_0 \mathbf{E}, \quad \mathbf{H}_{rad} \perp \mathbf{E} \tag{6.100}$$

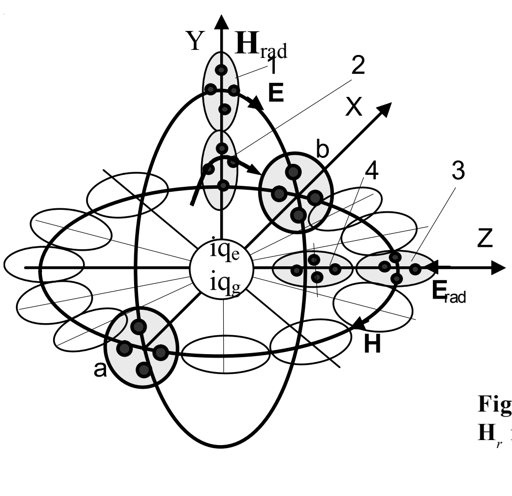

Fig. 6.9. Formation of radial fields $\mathbf{E}_r$ and $\mathbf{H}_r$ in the photon rotors.

The identical pattern may also be observed in the magnetic rotor **H** of the photon where the coupling of the magnetic charges in the quantons 3 and 4 induces in the plane of the rotor the radial electrical field $\mathbf{E}_{\mathrm{rad}}$ in accordance with (6.19) and taking into account the attenuation coefficient k_{at}

$$\mathbf{E}_{rad} = k_{at}\,\mu_0 C_0 \mathbf{H}, \quad \mathbf{E}_{rad} \perp \mathbf{H} \tag{6.101}$$

The expressions (6.100) and (6.101) do not correspond to the previously presented equations (6.96)...(6.19) because of the presence of the attenuation coefficient k_{at}. The point is that the equations (6.96)...(6.99) describe the field in the disc of the photon rotor consisting of only a single layer of quantons; in this case, nothing interferes with interaction in the rotor. However, in reality, as shown previously, the photon rotor is a multilayer formation consisting of a large number of quantons. For example, for a photon with $\lambda = 630$ nm, the number of layers consisting of quantons in the disc of the rotor is of the order of 10^5 layers at the mean thickness h_λ of the disk of the rotor of the order of 10^{-20} m (6.56)

$$h_\lambda = \frac{2S_{ef}}{\lambda} = 3.4 \cdot 10^{-20}\,\mathrm{m} \tag{6.102}$$

It was shown in [1] that the strength of the field in the quantised medium is an average parameter as a result of random deformation and orientation polarisation of a large number of quantons which together determine the disruption of the electrical and magnetic equilibrium of the quantised medium. Therefore, investigating the multilayer photon rotor, it may be assumed that the fields in every individual layer of the rotor satisfy the equations (6.96)...(6.99). However, if the density of the layers is high, the interaction between the layers results in a weakening of the radial field $\mathbf{E}_{\mathrm{rad}}$ (6.102) and $\mathbf{H}_{\mathrm{rad}}$ (6.100) which is taken into account by introducing the attenuation factor k_{at}. Because of the random nature of orientation of the quantons in the rotors, it is almost impossible to create conditions in which the charges in the quantons of the adjacent layers do not disrupt the required orientation of the quantons in every individual layer.

In any case, the flux Φ_τ of the electrical field of the electrical rotor of the photon, penetrating through the quantons in the tangential direction in the cross-section of the rotor, should be equivalent to the flux Φ_{rad} of the field in the radial direction and governed by the condition of equivalence between electricity and magnetism in the photon rotors

$$\Phi_\tau = \frac{1}{C_0}\Phi_{\mathrm{rad}} \tag{6.103}$$

Taking into account the equivalence conditions (6.103), we can determine the value of the attenuation factor k_{at} in (6.100) and (6.101), taking into account the averaged-out parameters of the photon. For this purpose, it is necessary to determine the tangential Φ_τ and radial Φ_{rad} fluxes of the fields inside the photon rotor on the level of the mean lines of force at the distance λ/4 from the photon centre. Consequently, the tangential flux in the electrical rotor of the photon is determined by the averaged value of the strength **E** and the effective cross-section $S_{ef} = 2.15 \cdot 10^{-26}$ m^2 (6.38)

$$\Phi_\tau = \int_S \varepsilon_0 \mathbf{E} dS = \varepsilon_0 \mathbf{E} S_{ef} \tag{6.104}$$

To determine the radial flux, equivalent to the flux (6.104), it is necessary to determine the area S_{rad} which the radial flux penetrates at a distance of λ/4 from the photon centre. Consequently, the area S_{rad} has the form of a narrow ring with the thickness h_λ (6.102) and with the length of circumference determined by the radius equal to λ/4

$$S_{rad} = \frac{1}{2}\pi h_\lambda \lambda = \pi S_{ef} \tag{6.105}$$

Taking into account (6.100) and (6.105), we determine the radial flux of the magnetic field in the electrical rotor of the photon

$$\Phi_{rad} = \int_S \mathbf{H}_{rad} dS = \mathbf{H}_{rad} S_{rad} = \mathbf{H}_{rad} \pi S_{ef} = \pi k_{at} \varepsilon_0 C_0 \mathbf{E} S_{ef} \tag{6.106}$$

Substituting (6.106) and (6.104) into the condition (6.103) we determine the attenuation factor k_{at}

$$k_{at} = \frac{1}{\pi} \tag{6.107}$$

Taking into account (6.107), we write the radial components $\mathbf{E}_{rad}$ (6.101) and $\mathbf{H}_{rad}$ (6.100) of the strength of the field in the photon rotors

$$\mathbf{E}_{rad} = \frac{\mu_0}{\pi} C_0 \mathbf{H}, \quad \mathbf{E}_{rad} \perp \mathbf{H} \tag{6.108}$$

$$\mathbf{H}_{rad} = \frac{\varepsilon_0}{\pi} C_0 \mathbf{E}, \quad \mathbf{H}_{rad} \perp \mathbf{E} \tag{6.109}$$

If we consider a set of quantons in the magnetic rotor, then in accordance with (6.108) their magnetic axes should be oriented in the direction of the rotor of the electrical axes in the direction of radius from the photon centre. Evidently, the radial electrical component $\mathbf{E}_{rad}$ (6.108) of the magnetic photon can be taken into account by placing an imaginary electrical charge iq_e in the rotor centre. Identical considerations relate to the electrical rotor where the radial magnetic component $\mathbf{H}_{rad}$ (6.109) of the electrical rotor of the photon can be taken into account by placing an imaginary magnetic charge iq_g in the photon centre. The imaginary unity i indicates that the photon charges are imaginary and do not exist in reality.

The introduction of the imaginary charges iq_e and iq_g which change with time and the frequency of the photon field makes it possible to analyse the trajectory of the photon in the presence of external perturbing fields, for example, in optical media. The values of the imaginary charges iq_e and iq_g of the photon can be estimated by the strength of the fluxes of the field penetrating the cross-section S_{rad} (6.105) of the photon in the radial direction on the level of the mean line of the photon rotor taking into account (6.108) and (6.109)

$$\begin{cases} iq_e = \int\limits_S \varepsilon_0 E_{rad} dS = \varepsilon_0 E_{rad} S_{rad} = \varepsilon_0 \dfrac{\mu_0}{\pi} C_0 H \pi S_{ef} = \dfrac{HS_{ef}}{C_0} \\ iq_g = \int\limits_S H_{rad} dS = H_{rad} S_{rad} = \dfrac{\varepsilon_0}{\pi} C_0 E \pi S_{ef} = \dfrac{ES_{ef}}{\mu_0 C_0} \end{cases} \tag{6.110}$$

It should be mentioned that the values of the imaginary charges (6.110) correspond to the mean line of the photon rotors and are maximum for every wavelength of the photon. Taking into account the mean values of E (6.42) and H (6.43), we determine the maximum values of the imaginary charges iq_e and iq_g (6.110) of the photon through its constants (Table 6.1) for any wavelength λ:

$$\begin{cases} iq_e = \dfrac{HS_{ef}}{C_0} = \dfrac{2\varphi_g}{\pi C_0 \lambda} S_{ef} = \dfrac{2\varepsilon_0 \varphi_e S_{ef}}{\pi\lambda} \\ iq_g = \dfrac{ES_{ef}}{\mu_0 C_0} = \dfrac{2\varphi_e}{\pi \mu_0 C_0 \lambda} S_{ef} = \dfrac{2\varphi_g S_{ef}}{\pi\lambda} \end{cases} \tag{6.111}$$

From (6.111) we obtain a relationship between the imaginary charges iq_e and iq_g of the photon rotors

$$iq_g = C_0 iq_e \tag{6.112}$$

Expression (6.112) confirms the accuracy of calculations because it corresponds to the relationship between the magnetic g and electrical e charges: $g = C_0 e$ [1].

Equation (6.111) makes it possible to determine the imaginary charges iq_e and iq_g of the photon for any wavelength λ through electrical or magnetic constants. In particular, for λ = 630 nm we determine the values of the imaginary charges iq_e and iq_g through the constants in Table 1

$$\begin{cases} iq_e = \dfrac{2\varepsilon_0\varphi_e S_{ef}}{\pi\lambda} = 10^{-25}\,\mathrm{C} \\ iq_g = \dfrac{2\varphi_g S_{ef}}{\pi\lambda} = 3\cdot 10^{-17}\,\mathrm{Dc} \end{cases} \tag{6.113}$$

In the limiting case, in annihilation of the electron to radiation with the photon energy of 0.511 MeV, the wavelength of the gamma quantum, equal to the Compton wavelength of the electron, is λ_0 = 3.86·10^{-13}m (6.32). Consequently, it is possible to determine the limiting iq_{emax} and iq_{max} imaginary charges of the photon with the energy of 0.511 MeV, emitted by the electron at the moment of its annihilation

$$\begin{cases} iq_{e\max} = \dfrac{2\varepsilon_0\varphi_e S_{ef}}{\pi\lambda_0} = e = 1.6\cdot 10^{-19}\,\mathrm{C} \\ iq_{g\max} = \dfrac{2\varphi_g S_{ef}}{\pi\lambda_0} = g = 4.8\cdot 10^{-11}\,\mathrm{Dc} \end{cases} \tag{6.114}$$

As indicated by (6.114), the theory shows complete agreement for the imaginary charges of the photon at electron annihilation when the imaginary charges correspond in magnitude completely to the actual electrical charge e = 1.6·10^{-19} C of the electron and its imaginary magnetic charge g = 4.8·10^{-11} Dc [1]. In fact, equation (6.114) is also a verification equation and confirms that the parameters of the photon are linked directly with the parameters of the radiating electron.

When writing the equations (6.97)–(6.99) it was noted that they differ from the classic equations because they regard the photon as a relativistic particle when the electrical and magnetic rotors show flux linkage in the binding zones *a* and *b*. If in the region of the microworld of the elementary particles in Fig. 6.2 (dimensions 10^{-15} m) the rotors are still connected by the points *a* and *b*, then in transition to the region of the ultra microworld of the quantons (dimensions 10^{-25} m) the points *a* and *b* increase and transform to the zones *a* and *b*, including a large number of quantons. Naturally, the equations (6.108) and (6.109) determine the radial components of the field as components acting (effective) in any region of the photon rotor, with the exception of the zones *a* and *b*. For this reason, the application of the imaginary charges for estimating the radial fields of the photon rotors does not relate to the zones *a* and *b* in which the radial field is disrupted.

In a general case, for a photon with wavelength λ, the imaginary charges iq_e and iq_g can be written by means of the elementary electrical e and magnetic g charges taking (6.114) into account

$$\begin{cases} iq_e = e\dfrac{\lambda_0}{\lambda} \\ iq_g = g\dfrac{\lambda_0}{\lambda} \end{cases} \tag{6.115}$$

As indicated by (6.115), the imaginary charges iq_e and iq_g of the low-energy photon, emitted by an orbital electron, are given by the electrical e and imaginary magnetic g charges of the electron, and also by the ratio of the Compton wavelength of the electron λ_0 to the wavelength λ of the photon emitted by them. The imaginary charges iq_e and iq_g of the low-energy photon are always smaller in values than the elementary charges e and g. This is the case in which the imaginary charges iq_e and iq_g can have any fractional values of the integer elementary charges e and g.

The importance of the equations (6.111)...(6.115) is clear when it is necessary to estimate the force effect on the photon from the side of the external electrical, magnetic in electromagnetic fields. In this case, the complicated interaction of the rotor and radial fields of the photon with the external fields which can be calculated using the most complicated integral equations or numerical summation in computer processing, is replaced by a simpler interaction with the imaginary charges of the photon in accordance with the principle of superposition of the field. Naturally, this method greatly simplifies the calculation procedure and provides clear information on the physical processes.

The introduction of the imaginary photon charges is of special importance when evaluating the interaction of the photons with matter in the processes of reflection, refraction, penetration and scattering of the photons, regardless of the fact that these processes have been studied quite sufficiently. The slowing down of the photons in the optical media and their carrying away by the moving medium can be explained quite simply by the interaction of the photon fields with the fields of the structure of optical media. In this case, the replacement of the photon fields by the imaginary charges explains the wave trajectories of the photon in optical media when the path in the matter along the wave trajectory with the speed C_0 between the nuclei of the atoms of the structure of matter is treated as the path along a straight line with a lower phase speed C_p [2].

The movement of the photon in the optical media along the wave trajectory is determined by the harmonic (cosine or sine) nature of variation of the charges with time. In fact, the initial parameters in the evaluation of the charges (6.111) are the acting parameters of the rotors **E** and **H** which in transition to amplitude values change in accordance with the cosine law (6.82) with time. Correspondingly, in transition to the instantaneous parameters of the imaginary charges (6.115), it is necessary to transfer to their amplitudes, multiply by $\sqrt{2}$ and by adding the time function of the cosine

$$\begin{cases} iq_e = e\dfrac{\lambda_0\sqrt{2}}{\lambda}\cos\left(\dfrac{2\pi}{T}t\right) \\ iq_g = g\dfrac{\lambda_0\sqrt{2}}{\lambda}\cos\left(-\dfrac{2\pi}{T}t\right) \end{cases} \tag{6.116}$$

On the other hand, the imaginary charges iq_e and iq_g are characterised by a non-classic distribution in movement away from the photon centre. The distribution is also described by the cosine distribution (6.86) in relation to the distance r (Fig. 6.7). To describe the distribution of the photon charge in relation to the distance, the origin of the coordinates should be transferred from the point (a) in Fig. 6.7 to the centre 0, i.e., the origin of the coordinates should be moved by $1/4\lambda$. In this case, the cosine function changes to the sine function, determining the distribution of the charge in movement away from the centre of the photon

$$\begin{cases} iq_e = iq_e\sin\left(\dfrac{2\pi}{\lambda}r\right) \\ iq_g = iq_g\sin\left(\dfrac{2\pi}{\lambda}r\right) \end{cases}, \quad r \le \frac{\lambda}{2} \tag{6.117}$$

Since the origin of the coordinates has been transferred by a quarter of the wavelength $1/4\lambda$, and correspondingly, by $1/4T$, the distribution of the imaginary charge with time (6.115) can also be described by the sine function. Consequently, combining (6.116) and (6.117), we write the generalise function of distribution of the imaginary charges iq_e and iq_g of the photon in time and space connected with the centre of the photon

$$\begin{cases} iq_e = e\dfrac{\lambda_0\sqrt{2}}{\lambda}\sin\left(\dfrac{2\pi}{T}t\right)\sin\left(\dfrac{2\pi}{\lambda}r\right) \\ iq_g = -g\dfrac{\lambda_0\sqrt{2}}{\lambda}\sin\left(\dfrac{2\pi}{T}t\right)\sin\left(\dfrac{2\pi}{\lambda}r\right) \end{cases}, \quad r \le \frac{\lambda}{2} \tag{6.118}$$

Evidently, in quantum electrodynamics, the distribution of the central charge in time is described by such a complicated function (6.118), firstly when the action of the charges is localised in the region $r \le \lambda/2$. Evidently, the imaginary charges of the photon are not point charges and have finite dimensions, restricted by the classic radius of the electron r_e.

The harmonic variation of the imaginary charges of the photon in time with the frequency of the electromagnetic field explains why it is not possible to deflect the trajectory of the photon in the static electrical and magnetic fields, although in reality in a static field this trajectory is described by a harmonic function with a very small deflection amplitude. However, these are already problems of the control of the photon trajectory which are outside the framework of these investigations, like the investigations of the organisation and synchronisation of wave packets from a large number of photons which determine coherent radiation.

Figure 6.10 shows the two-rotor full-wave structure of a low-energy photon emitted by an orbital electron when the photon diameter is equal to the wavelength of its electromagnetic field. Naturally, this structure of the photon combines the results of the previously mentioned investigations and satisfies the conditions of proportionality of photon energy to the frequency of the electromagnetic field.

The low-energy photon, emitted by the electron, has a two-rotor structure consisting of electrical and magnetic rotors. The radial cross-section of the low-energy rotors has the form of an ellipse elongated into a narrow strip because of the very small thickness h_λ (6.56) of the rotor in comparison with the wavelength. The electrical and magnetic fields of the rotors of the photon are situated in the orthogonal polarisation planes and have the common intersection line in the direction of the speed vector $\mathbf{C}_0$ on the X axis. This photon axis is referred to as the main axis. In addition, the polarisation planes of the photon can rotate around the main axis X with the cyclic frequency ω defining the photon as a spherical particle with the diameter equal to wavelength.

In the electrical rotor, the vector of the tangential strength **E** of the electrical field circulates around the circumference, changing with time and in space in accordance with the cosine law and functions (6.87) and

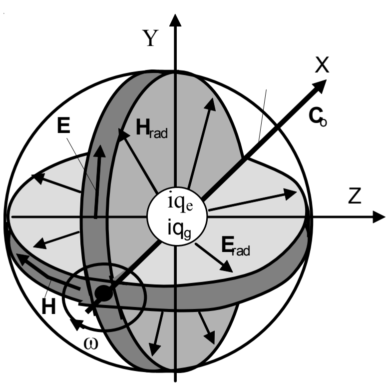

Fig. 6.10. The two-rotor structure of the low-energy photon emitted by the orbital electron.

(6.86). In addition, the tangential vector of the strength **E** of the electrical field induces the radial vector of the strength of the magnetic field $\mathbf{H}_{rad}$ (6.109) which is a function of vector **E**. The radial magnetic field $\mathbf{H}_{rad}$ can also be taken into account by introducing the imaginary magnetic charge iq_g (6.118) which is situated in the photon centre but its effect extends only to the electrical rotor. Naturally, the energy of the electrical rotor should be divided equally between its electrical and magnetic components. However, on the whole, this does not change the energy balance (6.78) of the photon because the energy in the magnetic rotor is also divided into halves between the magnetic and electrical components.

In the magnetic rotor, the vector of tangential strength **H** of the magnetic field circulates around the circumference changing with time and in space in accordance with the cosine law and functions (6.87) and (6.86). In addition to this, the tangential vector of strength **H** of the magnetic field induces the radial vector of the strength of the electrical field $\mathbf{E}_{rad}$ (6.108), which is a function of vector **H**. The radial electrical field $\mathbf{E}_{rad}$ can also be taken into account by introducing the imaginary electrical charge iq_e (6.118) which is situated in the photon centre but its effect extends only to the magnetic rotor.

In movement in the quantised medium, the photon with the structure shown in Fig. 6.10 leaves an electromagnetic trace which does not differ from the classic electromagnetic wave with transverse oscillations of the vectors of the strength of the electrical and magnetic fields (Fig. 6.8).

Thus, the investigations have made it possible to determine the structure of the low-energy photon (Fig. 6.8) and obtain its calculated parameters which satisfy the conditions of proportionality of the photon energy to the frequency of the electromagnetic field of the photon. This removes for the photon all the contradictions determined by the corpuscular–wave dualism, with the structure of the photon treated as a corpuscule in the form of a bunch of localised energy whose movement is determined by the wave transfer of energy of the electromagnetic polarisation of the quantised medium with the speed of light C_0.

6.6. Reasons for the deceleration of light in the optical medium

It is well known that all the optical matter media show the deceleration of the speed of light in comparison with vacuum, i.e., with the quantised medium. Current views on this problem contain only misunderstandings and alogisms where one claim of the absence of the light-bearing properties of the space does not correspond to experimental observations, although the propagation of light in space is detected literally all the time.

Nobody has shown that the light-bearing (luminiferous) medium is not required for the propagation of the electromagnetic wave because in these experiments it would be necessary to exclude the space-time from the experiments, i.e., get rid of the quantised medium. This is required by an experimental procedure in which exclusion of one of the factors has no effect nor influences the result. In this case, a disputable factor is the light-bearing medium, i.e., vacuum space. Here only the exclusion of the light-bearing medium from the experiment, as a disputable factor, can prove that the light-bearing medium is not required for light propagation. This is not realistic. It appears that the theoreticians do not have the experimental procedure and the experimentators do not have the astuteness of the mind of theoreticians.

In [2] it was shown that the imaginary deceleration of light in an optical medium is determined by the wave trajectory of movement of a photon with the speed of light C_0 inside the optical medium. The speed of light C_0 is determined by the parameters of the quantised medium as a light-bearing medium, and the speed of light C_0 is not connected to any extent with the optical medium which is an integral part of the quantised space-time. The optical medium causes perturbation of the straight movement of the photon and transverse vibrational deviations of the photon from the straight line movement. These transverse deviations are taken into account by the refractive index of the optical medium n_0:

$$n_0 = \frac{C_0}{C_{p0}} > 1 \tag{6.119}$$

where C_{p0} is the phase speed of the photon in the optical medium, m/s.

Phase speed C_{p0} determines the apparent speed of the photon in the optical medium along the straight line ℓ_x in the direction of, for example, the X axis during time t_0:

$$C_{p0} = \frac{\ell_x}{t_0} = \frac{C_0}{n_0} \tag{6.120}$$

In fact, as a result of movement of the photon in the optical medium along the perturbed wave trajectory during time t_0, the photon travels distance ℓ_0 in the quantised medium with the speed C_0

$$C_0 = \frac{\ell_0}{t_0} \tag{6.121}$$

Solving jointly (6.121) and (6.120), we determine the true length ℓ_0 of the path of the photon in the optical medium

$$\ell_0 = n_0 \ell_x \tag{6.122}$$

For example, for a pipe 1 m long with water with the refractive index n_0 = 1.33, the length of the path of the photon ℓ_0 (6.122) in the quantised medium inside the water is 1.33 m.

Equation (6.122) determines the linear dependence of the trajectory of the photon which in the first approximation should have the form of a broken periodic line determining the wave trajectory of the photon in the optical medium. However, this does not mean that the wave trajectory of the photon should in fact be represented by a broken line. It can already be assumed that the transverse deviations of the photon from the straight trajectory are extremely small. For this reason, the geometrical optics could not record transverse deviations of the photon inside the optical medium and should record only the external refractive index n_0 (6.119).

In order to continue investigations of the movement of the photon in optical media, it is necessary to verify another version of the possible deceleration of light, associated with gravitational deceleration in the vicinity of the atomic nucleus in accordance with (6.2). In the EQM theory, the speed of light C is a variable quantity and depends in a general case on the value of the gravitational potential C^2 of the quantised medium. In the conditions of non-relativistic speeds of movement of the optical medium at γ_n = 1 from (6.2) we obtain the deceleration of the speed of light C in comparison with C_0 in the vicinity of the mass m_0 of the atomic nucleus of the lattice of the optical medium at the distance r

$$C = C_0\sqrt{1-\frac{\varphi_n}{C_0^2}} = C_0\sqrt{1-\frac{Gm_0}{C_0^2 \cdot r}} \tag{6.123}$$

Equation (6.123) shows that in the absence of a gravitational perturbation, when the Newton potential is equal to 0, i.e., $\varphi_n = 0$, the speed of light is equal to the speed in the non-perturbed quantised medium, i.e., $C = C_0$. In the presence of a gravitational perturbation of the quantised medium, the speed of light decreases in accordance with (6.123). We introduce the coefficient of gravitational deceleration n_G of the speed of light in a gravitation-perturbed quantised medium, transforming (6.123)

$$n_G = \frac{C_0}{C} = \frac{1}{\sqrt{1-\frac{\varphi_n}{C_0^2}}} \tag{6.124}$$

From (6.124) we remove the Newton perturbing potential φ_n as a function of the coefficient of the gravitational deceleration of the speed of light n_G

$$\varphi_n = C_0^2 - C^2 = C_0^2\left(1 - \frac{C^2}{C_0^2}\right) = C_0^2\left(1 - \frac{1}{n_G^2}\right) \quad (6.125)$$

The equations (6.123)–(6.125) determine the relationship of the deceleration of light in the vicinity of the gravitational mass with the Newton perturbation potential φ_n. Consequently, it is possible to explain the decrease of the speed of light as a result of the gravitational perturbation of the quantised medium inside the optical medium in the vicinity of the atomic nuclei of the molecular lattice.

We examine an example in which the optical medium is represented by water (Fizo's experiment). Liquid water is regarded as some randomly oriented tetrahedral molecular network whose nodes contain oxygen atoms O, connected together by two hydrogen atoms H_2. Interatomic spacing O–H is ~0.1 nm, = 10^{-10}m. Further, we determine the gravitational perturbation potential φ_n in the middle $r \sim 0.5\cdot10^{-10}$ m between the atoms O–H through the masses of the oxygen nuclei m_O~$2.7\cdot10^{-26}$ kg and hydrogen nuclei m_H~$1.67\cdot10^{-27}$ kg

$$\varphi_n = G\frac{(m_O + m_H)}{r} \approx 0.4\cdot10^{-25}\,\mathrm{m}^2/\mathrm{s}^2 \quad (6.126)$$

If the perturbing gravitational potential φ_n (6.126) is substituted into (6.123) and (6.124), it may easily be shown that it cannot have any significant effect on the deceleration of light in water because its value is extremely small. Even if the calculations are carried out using the gravitational potential on the surface of the atomic nuclei, it is still is incommensurably smaller in order to observe a noticeable deceleration of light.

We can determine the value of the required gravitational potential whose effect on the quantised medium is equivalent to the deceleration of light by water. In this case, coefficient n_0 (6.119) should be compared with the coefficient n_G (6.124) of the deceleration of light by the gravitational field:

$$n_0 = n_G, \qquad \frac{C_0}{C_{p0}} = \frac{C_0}{C} \quad (6.127)$$

Equation (6.127) determines the condition of equivalence of the speed of light in the optical medium perturbed by a strong gravitational field

$$C_{p0} = C \quad (6.128)$$

To determine the gravitational potential having a strong effect on the light equivalent to the deceleration of light by water, in (6.125) n_G is substituted by the coefficient n_0 = 1.33 of the deceleration of light by water

$$\varphi_n = C_0^2\left(1-\frac{1}{n_0^2}\right) = 0.43\cdot C_0^2 = 3.9\cdot 10^{16}\,\mathrm{m}^2/\mathrm{s}^2 \tag{6.129}$$

The value of the required gravitational potential (6.129) is comparable with the gravitational Newton potential C_0^2 on the surface of a black hole [2]. For the gravitational fields to have any effect on the deceleration of light equivalent to the effect of water, as shown by calculations, the gravitational Newton potential (6.129) must be close to the gravitational potential $9\cdot 10^{16}$ $\mathrm{m}^2/\mathrm{s}^2$ (or J/kg) of a black hole. This condition cannot be fulfilled in the case of optical media. Thus, the results of calculations reject completely the assumption on the reasons for gravitational deceleration of light in optical media.

Light can be regarded as an electromagnetic wave in the optical medium with the parameters for water $\varepsilon = 81$. In this case, the speed of light in water should correspond to the refractive index $\sqrt{\varepsilon} = 9$. This value differs greatly from the actual refractive index $n_0 = 1.33$ of light by water. This is so even if we accept the Lorentz hypothesis on the possible reemission of the photon by the optical medium which requires time and is a factor of reduction of the speed in the optical medium. Nevertheless, the difference in comparison with the experiments remains too large to be the reason for the deceleration of light.

Thus, a brief analysis of the possible reasons for the deceleration of light in optical media shows that the only possible reason is the periodic refraction of light inside the lattice of the optical medium which causes transverse deviations of the photon trajectory from the straight line, ensuring movement of the photon along a wave trajectory.

6.7. Probable capture of atomic centres of the lattice of the optical medium by a photon

Thus, the only working concept remains a concept of the movement of light in the optical medium along a wave trajectory which in the final analysis determines the refractive (deceleration) index n_0 (6.119). There are all the conditions for claiming this which result from the structure of the photon or, more accurately, its configuration of the electromagnetic field whose radial components can be represented on the basis of the equivalent effect by the imaginary charges iq_e and iq_g (6.115).

By their nature, the imaginary charges iq_e and iq_g (6.115) of the photon are variable charges in time (6.116) because they are formed by the variable field of the photon. In a general case, any optical medium (solid, liquid, gaseous) can be represented by a molecular network (cell), irrespective of the configuration of the cells, with the nodes of the cells containing atomic nuclei with the electrical charge of positive polarity. Consequently, the interaction of the variable imaginary charge of the photon with the electrical charge of positive polarity of the atomic nucleus generates variable forces, resulting in transverse oscillations of the trajectory of the photon. Taking into account that the radial electrical field of the photon and its imaginary charge are situated in the polarisation plane, the same plane will be characterised by transverse oscillations of the photon in relation to the straight line determining the wave trajectory of the movement of the photon in the optical medium. In this case, it is also necessary to take into account the rotation of the polarisation plane of the photon.

This complicated (both with respect to configuration and space and with variation with time) interaction of the fields of the moving photon with??? the speed of light inside a molecular network of the optical medium cannot as yet been determined directly. The replacement of the photon field by imaginary charges with equivalent effects greatly simplifies not only the calculations but also the physical understanding of the processes of interaction of the photon with a molecular network consisting of the atomic nuclei in the nodes.

As reported, the O–H atomic spacing for the tetrahedral molecular network of water is ~0.1 nm = 10^{-10} m. The diameter of the optical photon of, for example, a helium–neon laser is equal to its wavelength $\lambda = 0.63 \cdot 10^{-6}$ m (red light). It appears that the optical photon of red light is four orders of magnitude larger than the cell of the molecular network of water. However, it can be assumed that the calculation dimensions of the imaginary photon charges do not exceed the classic radius of the electron $r_e = 2.8 \cdot 10^{-15}$ m. This means that the calculation diameter of the imaginary charge of the photon is five orders of magnitude smaller than the cell of the molecular network of water.

If we use the classic approach to the movement of the photon in the optical medium, then the photon during its movement in water should capture by its volume a large number of atoms, forming the structure of water. We estimate the number N_a of the atoms which appear inside the volume V_v of the photon with the radius equal to the wavelength of, for example, red light with $\lambda = 0.63 \cdot 10^{-6}$ m, calculating the volume of the atom V_a occupied in the shell of the molecular network of the water of the medium through the mean atomic radius $r_a = 0.1$ nm

$$N_a \approx \frac{V_v}{V_a} = \frac{\frac{1}{6}\pi\lambda^3}{r_a^3} = 1.3 \cdot 10^{11}\,\frac{\text{atoms}}{\text{photon}} \qquad (6.130)$$

Taking into account that the electrical charge of the atom nucleus is compensated by the charges of the orbital electrons, it would appear that the molecular network (lattice) of the optical medium should not have any significant effect on the imaginary charge and trajectory of the photon. In fact, such a large number of the atoms per photon of the order of 10^{11} (6.130) creates inside the photon a uniform concentration of the atoms throughout the volume of the photon, and the electrical field of the nuclei of these atoms is fully compensated by the orbital electrons and should have no effect on the imaginary electrical charge of the photon.

However, these considerations would be valid if the imaginary electrical charge of the photon had a spherical symmetry, i.e., its electrical field would operate in the volume of the sphere as, for example, the electrical charge of the electron with the spherical symmetry. However, the effect of the imaginary electrical charge of the optical photon is located in the volume V_r of a very narrow region of the photon rotor determining one of the polarisation planes. The volume V_r of the rotor of the optical photon, as shown previously, is incomparably smaller than the entire volume of the photon V_v, i.e., $V_r \ll V_v$. Therefore, the interaction of the photon with the molecular network (lattice) of the optical medium should not be determined by calculating the entire spherical volume of the photon V_v and it should be determined only by calculating the volume of its rotor V_r.

In order to solve the problem of interaction of the photon with the molecular network (lattice) of the optical medium, it is necessary to transfer to probability calculation methods. It is evident that from the entire variety of the atomic nuclei, the photon should interact on the wavelength only with a single atomic nucleus, synchronising the effect of transverse forces and oscillations with a period of the electromagnetic field at the wavelength. The interaction of the imaginary electrical charge of the photon iq_e with the charge q_n of the atomic nucleus in the periodic sequence ensures the wave trajectory of the photon in the optical medium only in this case. For this, the probability p_{n1} of capture of photons of the entire 1 atomic nucleus should be equal to 1 at the wavelength λ

$$p_{n1} = 1\,\frac{\text{nuclei}}{\lambda} \qquad (6.131)$$

The condition (6.131) determines the non-classic probabilistic approach to the quantum phenomena in the optical media when the wave processes during movement of the photon relate not only to its electromagnetic field but also the trajectory of motion along a wavy line. This means that the trajectory of the photon itself has the form of a wave. This wave should be characterised as the wave of a geometrical type, describing the movement of the photon in the optical medium. Therefore, the condition (6.131) is referred to as the wave condition for the photon in the optical medium.

It is now necessary to verify the extent to which the parameters of the photon in movement of the optical medium satisfy the wave condition (6.131). Taking into account that atomic nuclei, like the atoms themselves, with their number N_a (6.130) inside the photon are uniformly distributed throughout its volume V_ν, we can estimate the number n_n of the atomic nuclei of the molecular network (lattice) per volume of the rotor of the photon V_r

$$n_n = \rho_n V_r = N_a \frac{V_r}{V_\nu} \tag{6.132}$$

As indicated by (6.132), the distribution of the atomic nuclei inside the photon is proportional to the volume of its compound part. Volume V_r of the rotor of the optical photon is determined on the basis of the diameter of the photons equal to its wavelength λ and thickness $h_\lambda = 2S_{ef}/\lambda$ (6.56) of the photon rotor (Fig. 6.8)

$$V_r = \frac{1}{4}\pi\lambda^2 h_\lambda = \frac{1}{2}\pi\lambda S_{ef} \tag{6.133}$$

The volume of the rotor (6.133) is determined for the full-wave model of the photon. Substituting (6.132) into (6.131), and taking into account (6.130), we determine the number n_n (6.132) of the atomic nuclei inside the rotor specifically for the photon of red light with $\lambda = 630$ nm and the rotor thickness $h_\lambda = 3.4 \cdot 10^{-20}$ m (6.56)

$$n_n = N_a \frac{V_r}{V_\nu} = N_a \frac{\frac{1}{4}\pi\lambda^2 h_\lambda}{\frac{1}{6}\pi\lambda^3} = \frac{3}{2} N_a \frac{h_\lambda}{\lambda} = 0.01 \frac{\text{nuclei}}{\text{photon}} \tag{6.134}$$

Comparing the huge number of the atoms $N_a \approx 1.3 \cdot 10^{11}$ (6.130) in the volume of the photon energy and the incomplete number of the atomic nuclei $n_n = 0.01$ (6.134) included in the photon rotor, we face a paradoxic situation in which the structure of the photon, which has the unique properties of the rotors, is not capable of including even one atomic nucleus in the composition of the rotor. On the other hand, such fractional parameters as $n_n = 0.01$ (6.134), which is considerably smaller than 1, cannot determine the number of nuclei in the photon rotor and should be regarded as the probability p_n of the atomic nucleus of the molecular network of water entering the photon rotor at the wavelength λ

$$p_n = n_n = N_a \frac{V_r}{V_\nu} = 0.01 \frac{\text{nuclei}}{\lambda} \tag{6.135}$$

Using equation (6.135) we can estimate the length x_0 of the free path of the photon inside the optical medium to collision of the photon rotor with the atomic nucleus of the molecular network

$$x_0 = \frac{\lambda}{p_n} = 100\lambda \tag{6.136}$$

The free path of the red light photon in water is of the order of 100 λ. It turns out that the photon in interaction with the optical medium does not satisfy the wave condition p_{n1} = 1 (6.131). The additional conditions are necessary for the photon to be able capture one atomic nucleus at 1 λ wavelength of the free path in the optical medium.

This additional condition is the rotation of the photon in the optical medium or, more accurately, the rotation of its polarisation planes, i.e., rotors around the main axis X (Fig. 6.10). We can estimate the cyclic frequency ω of rotation (angular speed) of the photon and the angle α_ω through which it is necessary to rotate the polarisation planes of the photon to ensure that the photon at 1λ wavelength captures by its field one atom nucleus of the molecular network (lattice) of the optical medium. For this purpose, the probability parameter n_n = 0.01 in (6.135) must be increased to the probability p_{n1} = 1 (6.131) of the wave condition, determining the required volume V_ω of the photon so that in rotation around the X axis through the angle α_ω the photon rotor could capture one nucleus

$$p_{n1} = N_a \frac{V_\omega}{V_\nu} = 1 \frac{\text{nuclei}}{\lambda} \tag{6.137}$$

From (6.137) we determine the volume V_ω defined by the photon rotor in rotation of the photon around the main axis X for p_{n1} = 1 taking (6.130) into account

$$V_\omega = \frac{V_\nu}{N_a} = V_a = r_a^3 \tag{6.138}$$

The volume V_ω (6.138) forms as a result of rotation of the plane of the photon rotor through the angle α_ω

$$V_\omega = \frac{\pi\lambda^3}{6} \frac{\alpha_\omega}{2\pi} = r_a^3 \tag{6.139}$$

From (6.139) we determine the angle α_ω of rotation of the photon around the main axis X during the period T to ensure capture of one nucleus by the photon, and determine the specific value of the angle α_ω for r_a = 0.1 nm and the red light photon with λ = 630 nm

$$\alpha_\omega = \frac{12r_a^3}{\lambda^3 k_3} = 0.48 \cdot 10^{-10}\,\text{rad} \tag{6.140}$$

The rotation of the polarisation planes of the photon through the angle α_ω to ensure that the photon can capture one atomic nucleus of the network of the optical medium should take place during the period T at the wavelength λ. Consequently, we can determine the angular speed of rotation of the photon around the main axis X, for example, for λ = 630 nm

$$\omega = \frac{\alpha_\omega}{T} = \frac{\alpha_\omega}{\lambda} C_0 = 2.3 \cdot 10^4 \frac{\text{rad}}{\text{s}} = 3.66 \cdot 10^3 \text{s}^{-1} \tag{6.141}$$

For the red light photon with λ= 630 nm to capture only one atomic nucleus in a water optical medium, the photon should rotate with a frequency of 3660 rev/s (6.141).

Thus, the calculation show that the unique structure of the photon enables synchronous capture of a single atomic nucleus in rotation of the photon around the main axis in the direction of movement at the wavelength 1λ. This satisfies the wave equation (6.131) which determines the movement of the photon along the wave trajectory inside the optical medium.

For the photon to capture by its field an atomic nucleus at the wavelength 1λ, the photon should rotate in the optical medium with the angular speed ω (6.141). The reasons for the rotation of the polarisation planes of the photon have not as yet been examined. However, when discussing the capture of the atomic nucleus by the photon, this event should be regarded as reciprocal when the atomic nucleus also takes part in photon capture. This is expressed in the fact that the interaction of the nucleus and the photon is determined not only by the force of attraction and repulsion of the electrical charges of the nucleus and the imaginary electrical charge of the photon but also by the interaction of the electrical dipole moment of the photon rotor determined by the polarisation of the quantised medium inside the rotor by the radial electrical field.

The dipole electrical moment $\mathbf{P}_e$ of the photon rotor can be estimated by the polarisation of the quantised medium by the radial electrical field $\mathbf{E}_{rad}$:

$$\mathbf{P}_e = \int_V \varepsilon_0 \mathbf{E}_{rad} dV = 0 \tag{6.142}$$

If we integrate (6.142) over the entire volume of the photon rotor, then because of the symmetric nature of the radial vector of the strength $\mathbf{E}_{rad}$ directed to all sides in the rotor plane, the electrical dipole moment of the rotor is equal to 0. However, it will be equal to 0 if the integral (6.142) is taken from half of the photon rotor volume dissected by the X axis

$$\mathbf{P}_e = \int_{0.5V} \varepsilon_0 \mathbf{E}_{rad}\, dV \neq 0 \tag{6.143}$$

Figure 6.11 shows schematically the effect of the electrical field $\mathbf{E}_n$ of the charge of the atomic nucleus $+q_n$ on the imaginary electrical charge iq_e and the dipole moment $\mathbf{P}_e$ (6.143) on half the photon rotor. The photon is shown in projection on a plane which is normal to the X axis and the direction of movement. The dipole moment $\mathbf{P}_e$ of the rotor is situated in the plane $Z0X$ of the photon rotor, to the right and left of the X axis. In total, two dipole moments compensate each other (6.142). However, when the photon rotor starts to interact with the electrical charge of the atomic nucleus $+q_n$, its electrical field $\mathbf{E}_n$, penetrating the nearest half of the photon rotor, influences the dipole moment $\mathbf{P}_e$ and generates the mechanical moment $\mathbf{M}_e$, which additionally twists of the photon to the complete capture of the nucleus $+q_n$ by the rotor (Fig. 6.11). In this case, half of the photon rotor is regarded as an electrical dipole with the moment $\mathbf{P}_e$, which in the external electrical field $\mathbf{E}_n$ of the nucleus tries to rotate with its axis along the lines of force of the external field of the charge, determining the mechanical moment $\mathbf{M}_e$.

However, the electrical field $\mathbf{E}_n$ of the nucleus which has not as yet been trapped by the rotor cannot influence the imaginary electrical charge iq_e of the photon because the effect of the charge iq_e is situated only in the plane of the rotor. The second factor, ensuring additional rotation of the photon around the main axis, is the formation of the transverse Lorentz force in interaction of the magnetic rotor with the charge of the nucleus of the atom of the lattice. This factor requires additional analysis and is not investigated in this book.

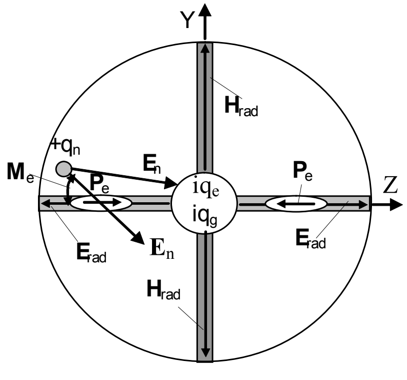

Fig. 6.11. The effect of the electrical field $\mathbf{E}_n$ of the charge of the atomic nucleus $+q_n$ on the imaginary electrical charge iq_e and the dipole momentum $\mathbf{P}_e$ of the photon rotor.

It is important to note that the capture by the photon rotor of the nearest atomic nucleus starts with the formation of the mechanical moment $\mathbf{M}_e$ which additionally twists the photon to the complete capture of the nucleus $+q_n$ by the photon rotor. This is followed by the start of interaction of the charges $+q_n$ and iq_e which in the first half period of the alternating fields of the photon result in attraction of the charges and subsequently during the second half period in the repulsion of the charges. Taking into account that the electromagnetic mass of the atomic nucleus is considerably greater than the electromagnetic mass of the photon, only the photon can be deflected in the transverse direction. Transverse deflections of the photon are of the alternating type and determine in the final analysis its wave trajectory in consecutive capture of the atomic nuclei of the optical medium by the photon.

Probability calculations showed that the rotor of the photon in twisting through the angle α_ω (6.140) can capture during a period only one atomic nucleus of the molecular network (lattice) in the optical medium. The process is then cyclically repeated and determines the capture of the next atomic nucleus. Consequently, the trajectory of the photon in the direction of the X axis shows additional wave transverse deflections.

We can calculate the moments and forces acting on the photon inside the optical medium on the side of the molecular network and obtain the wave equation of movement of the photon in every specific case. However, this problem is outside the given subject taking into account the large volume of computing operations. In addition, the reason for this phenomenon of wave movement of the photon, determined by the periodic capture by the photon of the atomic nucleus in the optical medium has been studied sufficiently in order to understand the gist of the problem and continue further investigations.

In fact, the process of twisting of the photon around the X axis can be not only of the rotational character, determining the angular speed ω (6.141) of rotation, but may also oscillate in relation to the X axis where the angular oscillations in transfer from nucleus to nucleus are characterised by the variation of the sign of the angle $\pm\alpha_\omega$ (6.140). In this case, the cyclic angular rotation of the polarisation plane of the photon is not observed.

In the previously described probability calculations of the capture of the atomic nucleus by the photon we did not consider the effect of orbital electrons. In contrast to the atomic nuclei which can be regarded as static sites of the molecular network, the orbital electrons rotate around the atomic nucleus along complicated trajectories, forming an electronic cloud. We examine the probability model of capture of an orbital electron by a photon.

Figure 6.12 shows the calculation scheme of the probability capture of the orbital electron of the atom by the radial electrical field of the photon $\mathbf{E}_{rad}$. The term capture is used allegorically in this case because in fact no capture takes place and only the possibility of interaction of orbital electrons with the radial electrical field of the photon is estimated. The electronic cloud of the atom is represented by a spherical formation with the atomic radius r_a and the number of electrons Z_e in the volume V_a of the atom. The centre of the atom contains a nucleus with the charge $+q_n$ which is compensated by charges of the orbital electrons

$$q_n = eZ_e \tag{6.144}$$

The photon is shown in the projection of orthogonal rotors in the direction of movement along the X axis. The radial electrical field with the strength $\mathbf{E}_{rad}$ penetrates the atom through the centre and fully captures its nucleus. The effect of the imaginary electrical charge iq_e of the photon applies only in the plane of the photon rotor. The situation described evaluates the probability of capture of the atom nucleus by the photon rotor as equal to 1. Consequently, the interaction of the charges of the nucleus with the imaginary electrical charge of the photon is complete and determines the force of deflection of the photon in the direction towards the atom nucleus.

However, the interaction of the imaginary electrical charge of the photon with the charges of the orbital electrons is incomplete because the rotors of the photon penetrates only through a narrow region of the nucleus in which the probability density ρ_{e1} (or the density of probability [12]) of the electrons is evaluated by the partial derivative of the probability p_{e1} of the capture of the electron by the proton only in the part of the volume of the rotor of the photon V_e which penetrates through the atom without affecting the entire volume of the photon rotor

$$\rho_{e1} = \frac{\partial p_{e1}}{\partial V_e} \tag{6.145}$$

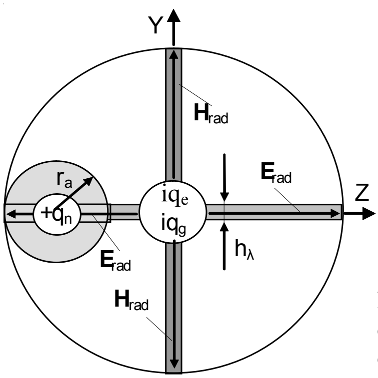

Fig. 6.12. Calculation of the probability of capture of the orbital electron by the radial $\mathbf{E}_{rad}$ electrical field of the photon.

The introduction into (6.145) of the partial derivatives with respect to the volume was intentional in order to distinguish the part of the volume of the photon rotor penetrating the electronic cloud. It is noteworthy that the probability density ρ_{el} (6.145) of the electrons in the volume V_e of the part of the rotor is numerically equal to their concentration g_n in the volume of the atom V_a, even when the particles of the volume are distributed nonuniformly, and their concentration is determined as a function of the coordinates (x, y, z)

$$\frac{\partial p_{e1}}{\partial V_e} = \rho_z(x, y, z) \tag{6.146}$$

The equation (6.146) can be solved if we know the distribution of the particles in the volume or the distribution of the probability density ρ_{e1} of the particles in the volume. If the instantaneous distribution of the electrons in the volume of the electronic cloud is not known, it can be assumed that the distribution of the electrons in every very narrow spherically symmetric (in relation to the centre of the atom) volume is uniform. Taking into account that the angular speed of rotation of the photon is very low (6.141) and the speed of the orbital electrons may reach relativistic speeds, the effect of rotation of the photon on the calculated probability of capture of the orbital electron can be ignored. If the rotor of the photon penetrates diametrically the electronic cloud or, more accurately, its layers with the uniform concentration of the electron, it can be assumed that the mean concentration of the electrons ρ_n in the volume of the rotor is represented by their averaged volume density

$$\rho_z = \frac{Z_e}{V_a} \tag{6.147}$$

Consequently, taking into account (6.147), equation (6.146) can be presented in the following form

$$\frac{\partial p_{e1}}{\partial V_e} = \frac{Z_e}{V_a} \tag{6.148}$$

We divide the variables in (6.148). Integration is carried out in the conditions of the partial derivative, disregarding the volume V_a, and we determine the probability ρ_{el} of capture of the orbital electron by the photon at the wavelength 1λ:

$$\int \partial p_{e1} = \frac{Z_e}{V_a} \int \partial V_e$$
$$p_{e1} = Z_e \frac{V_e}{V_a} \leq 1 \tag{6.149}$$

Probability p_{el} (6.149) of capture of a single orbital electron by a photon from the total number Z_e of the orbital electrons imposes restrictions on volume V_e

$$V_e \le \frac{V_a}{Z_e} \tag{6.150}$$

We determine the probability p_{el} (6.149) of capture of a single orbital electron by a photon with the optical medium represented by water with, as mentioned previously, the tetrahedral molecular network O–H. The oxygen atom may have a stronger effect on the photon than the hydrogen atom because the former has a large electrical charge of the nucleus. Thus, the number of the orbital electrons for the oxygen atom is $Z_e = 8$, and the atomic radius $r_a = 0.1$ nm.

Since the electronic cloud is spherically symmetric, the problem is simplified and it can be assumed that the electrons are uniformly distributed in every very narrow spherical region of the electronic cloud. Consequently, the nonuniform distribution of the electrons, especially in the given case, can be regarded as a uniform distribution in the volume of the atom with the atomic radius r_a and we can determine the average concentration ρ_n (6.147) of the electrons in the oxygen atom (for $Z_e = 8$ and $r_a = 0.1$ nm)

$$\rho_z = \frac{Z_e}{V_a} = \frac{Z_e}{\frac{4}{3}\pi r_a^3} = 1.91 \cdot 10^{10}\,\frac{\text{electrons}}{\text{m}^3} \tag{6.151}$$

Using the equation (6.149) we can determine the probability p_{el} of at least one orbital electron of the oxygen atom being in the region of the flat photon rotor at the wavelength 1λ, for example for a red light photon with $\lambda = 630$ nm and the thickness of the rotor $h_\lambda = 3.4 \cdot 10^{-20}$ m (6.56)

$$\begin{aligned} p_{e1} &= Z_e \frac{V_e}{V_a} = Z_e \frac{\pi r_a^2 h_\lambda}{\frac{4}{3}\pi r_a^3} = Z_e \frac{3h_\lambda}{4r_a} = Z_e \frac{3S_{ef}}{2r_a\lambda} = 2 \cdot 10^{-9} \\ p_{e1} &= Z_e \frac{V_e}{V_a} = \rho_z V_e = \rho_z \pi r_a^2 h_\lambda = 2 \cdot 10^{-9}\,\frac{\text{electrons}}{\lambda} \end{aligned} \tag{6.152}$$

Thus, the probability p_{v1} of capture of an orbital electron at wavelength 1λ by the radial $\mathbf{E}_{rad}$ electrical field of the photon (or the imaginary electrical charge) is estimated by a very low value of the order of 10^{-9} (6.152) (Fig. 6.4), regardless of the very high concentration ρ_n (6.147) of the electrons in the electronic cloud. Consequently, we can ignore the effect of orbital electrons on the trajectory of movement of the photon in the optical medium and this means that in interaction of the photon with the molecular network (lattice) of the optical medium it is necessary to take into account only interaction of the atomic nuclei with positive polarity, distributed in the nodes of the network (lattice), with the electrical charges q_n.

Attention should be given to the fact that the function of probability density of the electrons p_{e1} (6.146) in the orbital cloud of the atom is directly linked with the wave function of the electron through the probability amplitude $\psi|(x, y, z, t)|^2$ [34]

$$\frac{\partial p_{e1}}{\partial V_e} = \left|\Psi(x,y,z,t)\right|^2 \tag{6.153}$$

Consequently, integration of (6.153) over the entire volume of the atom V_a determines the normalisation conditions for a single orbital electron

$$p_{e1} = \frac{1}{Z_e}\int_V \left|\Psi(x,y,z,t)\right|^2 dV = 1 \tag{6.154}$$

In fact, when solving the probability problem of interaction of the photon with orbital electrons, it was not necessary to use the wave function of the electron. The photon itself is described by the classic wave equation (6.92) which completely satisfies the Maxwell conditions and the two-rotor structure of the photon. In particular, the wave equation of the photon determines the nature of its electromagnetic field which varies with time, including the radial electrical component. The specific features of interaction of this component with the electrical charges of the atomic nuclei in the optical medium create additional transverse wave oscillations of the photon during its movement in the direction of the X axis.

Analysing the current state of the theory of the photon in quantum electrodynamics [7], it is important to note the restrictions in the phenomenological model and the absence of any relationship with the structure of the photon because the two-rotor relativistic model of the photon was not available. This complicates physical interpretation of the phenomenological theory which is not capable of solving the previously described tasks; this can be carried out in a simple manner in the theory of Superunification. The completness of the quantum theory is essential only under the conditions of the effect of superstrong electromagnetic interaction (SEI) on the physical processes. In the present case, this interaction is determined by the presence of the quantised medium, i.e., the light-bearing medium.

The previously mentioned probability calculations enable us to evaluate the state of the photon in the optical medium:

1. The photon has unique properties of a self-setting system in movement in the optical medium. Self-setting of the photon is expressed in the fact that the photon captures only one atomic nucleus of the molecular network (lattice) of the optical medium at the wavelength 1λ, satisfying the wave condition $p_{n1} = 1$ (6.131), which determines the movement of the photon along a wavy trajectory.
2. The probability $p_{e1} \sim 10^{-9}$ (6.152) of capture of the orbital electron of the atom of the optical medium by the photon is expressed by a very small value. Consequently, we can ignore the effect of orbital electrons on the trajectory of movement of the photon in the optical medium. It is necessary to take into account only the interaction of the photon with the atomic nuclei.

The conclusions obtained for the results of probability calculations describe quite accurately the state of the photon in the optical medium and clarify the reasons for its wavy movement with longitudinal oscillations in relation to the direction of movement along a straight line. It would appear that the optical medium is crammed with the atomic nuclei and orbital electrons has the form of a high density network (lattice) and the photon cannot penetrate through this network without colliding with the orbital electron or atomic nucleus.

However, the probability calculations show that because of the specific features of the electromagnetic field of the photon rotors or, more accurately, the radial electrical field situated in a very narrow plane of the rotor, the probability $p_{e1} \sim 10^{-1}$ (6.140) of capture of the orbital electron by the photon almost completely excludes such a capture. If the photon satisfies the wave condition $p_{n1} = 1$ (6.131), the photon can capture one atomic nucleus at wavelength 1λ.

When discussing the peculiarities of the quantum theory which, it appears, is not governed by classic analysis, it is necessary to ask the question: do we know thoroughly the structure of the photon and elementary particles? The structure of the photon was not known prior to the development of the EQM theory and Superunification theory and attempts to explain the non-classic behaviour of the photon proved to be incorrect. Everything has its reason. It is necessary to find it.

In this respect, the photon behaves fully predictably because of the unique parameters of the two-rotor structure and the presence of radial fields in the rotors. Consequently, the photon can select the particles with which it should interact and with which it should not interact. However, this does not mean that the photon has a brain and selectively interacts inside the optical medium only with the essential particles, as a self-setting system.

In fact, this is the role of the specific features of the two-rotor electromagnetic field of the photon which is characterised by selective properties with respect to the nuclei of the atoms and orbital electrons.

6.8. Vector diagram of the complex speed of the photon in the optical medium

Taking into account the results, for further investigations of the complicated trajectory of the photon in the optical medium we express the refractive index n_0 (6.122) of the light as the ratio of the length of the trajectory of the photon along the straight line ℓ_x to the length of the wave trajectory ℓ_0, which characterises the deceleration of light inside the optical medium

$$n_0 = \frac{\ell_0}{\ell_x} = \frac{C_0}{C_{p0}} \qquad (6.155)$$

Figure 6.13 shows the vector diagram of the absolute speed C_0 of the light and its phase speed C_{p0} in accordance with (6.155) for a stationary optical medium. The absolute speed of the photon C_0 in the optical medium is the vector sum of the phase speed C_{p0}, with the longitudinal component along the X axis and the transverse component C_{z0} along the Z axis

$$\mathrm{C}_0 = \mathrm{C}_{p0} + \mathrm{C}_{z0} \qquad (6.156)$$

The modulus of absolute speed C_0 (6.156)

$$C_0 = \sqrt{C_{p0}^2 + C_{z0}^2} \qquad (6.157)$$

The tangent of the angle β_0 and the angle β_0 taking (6.157) and (6.155) into account

$$\mathrm{tg}\,\beta_0 = \frac{C_{z0}}{C_{p0}} = \frac{\sqrt{C_0^2 - C_{p0}^2}}{C_{p0}} = \sqrt{\frac{C_0^2}{C_{p0}^2} - 1} = \sqrt{n_0^2 - 1} \qquad (6.158)$$

$$\beta_0 = \mathrm{arctg}\sqrt{n_0^2 - 1} \qquad (6.159)$$

From (6.158) we determine the transverse speed of the photon C_{z0}

$$C_{z0} = C_{p0}\sqrt{n_0^2 - 1} = C_0 \frac{\sqrt{n_0^2 - 1}}{n_0} = C_0\sqrt{1 - \frac{1}{n_0^2}} \qquad (6.160)$$

The modulus of the vector of absolute speed C_0 is a constant in the local region of space because it is determined by the parameters of the quantised medium as the light-bearing medium inside the optical medium

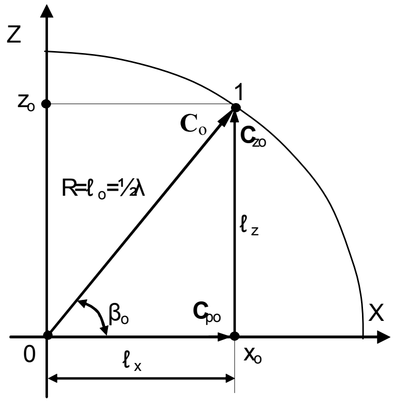

Fig. 6.13. Vector diagram of the absolute speed of light C_0 and its phase speed C_p in the optical medium.

$$C_0 = \text{const} \tag{6.161}$$

The vector diagram of speeds in Fig. 6.13 can be imaged on a complex plane, representing the longitudinal phase speed C_{p0} as the actual component and the speed C_{z0} as the apparent transverse component of the complex speed υ whose modulus C_0 is (6.157), where i is the imaginary unity

$$\upsilon = C_0 \cos\beta_0 + iC_0 \sin\beta_0 = C_0 \exp(i\beta_0) \tag{6.162}$$

Thus, analysis of the refractive index n_0 (6.155) shows that the phase speed C_{p0}, as the longitudinal component of the absolute speed of light C_0, is determined by the difference of the vectors: the absolute vector of speed C_0 and the transverse vector of speed C_{z0}

$$\mathrm{C}_{p0} = \mathrm{C}_0 - \mathrm{C}_{z0} \tag{6.163}$$

In particular, the presence of the transverse component C_{z0} determines the movement of the photon in the optical medium along a wavy trajectory. However, this is not yet indicated by the vector diagram in Fig. 6.14 which determines the linear–broken trajectory of the photon in the form of a triangular periodic function. This function links the linear parameters of the absolute path length ℓ_0 of the photon in the quantised medium with its longitudinal ℓ_x and transverse ℓ_z components

$$\ell_0^2 = \ell_x^2 + \ell_z^2 \tag{6.164}$$

$$\ell_0 = \sqrt{\ell_x^2 + \ell_z^2} \tag{6.165}$$

Using the path components ℓ_x and ℓ_z, we determine the tangent of the angle β_0

$$\operatorname{tg}\beta_0 = \frac{\ell_z}{\ell_x} = \sqrt{n_0^2 - 1} \tag{6.166}$$

From (6.166) we determine the transverse ℓ_z component of the photon path

$$\ell_z = \ell_x \sqrt{n_0^2 - 1} = \ell_0 \sqrt{1 - \frac{1}{n_0^2}} \tag{6.167}$$

Figure 6.14 shows the idealised linear–broken trajectory of the photon in the optical medium in the form of a periodic triangular function. The photon is represented by a circle in projection with the diameter equal to the wavelength λ. The centre of the photon contains the imaginary variable electrical charge iq_e.

The linear–broken trajectory of the photon is determined by the condition of periodic capture of the positively charged atomic nucleus with the charge $+q_n$ of the molecular network (lattice) of the optical medium. The photon starts capture of the atomic nucleus by the imaginary charge iq_e when it is situated at the distance 1/2λ from the charge $+q_{n1}$ of the nucleus. After 1/2λ when the imaginary charge iq_e comes closer to the charge $+q_{n1}$ of the nucleus, the current variable charge iq_e changes polarity and the photon starts to be repulsed from the charge of the nucleus $+q_{n1}$. After the next 1/2λ, the imaginary charge iq_e again changes polarity and starts capture of the next atomic nucleus 2 with the charge $+q_{n2}$, repeating the linear–broken trajectory at the period T.

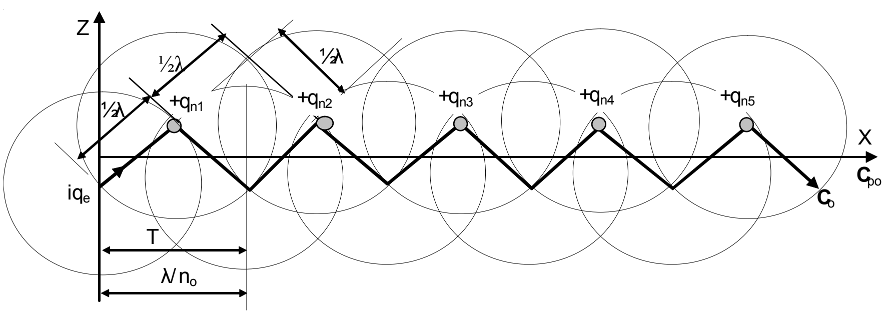

Fig. 6.14. The idealised linear–broken trajectory of the photon in the form of the triangular function in the optical medium in the conditions of periodic capture of the positively charged atomic nucleus of the molecular network.

The process is then periodically repeated and the photon at every wavelength λ gradually captures nuclei with the charges $+q_{n3}$, $+q_{n4}$, $+q_{n5}$, and so on. In the direction of the X axis and in the period T the photon travels the distance λ/n_0 which is shorter than the distance λ in movement along the linear–broken trajectory. However, the movement of the photon along the linear–

broken trajectory in the optical medium in the form of a periodic triangular function does not reflect the actual trajectory of the photon, although it makes it possible derive a number of important relationships between the parameters of the photon trajectory.

Figure 6.14 shows the section for the period T of the linear–broken trajectory of the photon in the form of a triangular function in the optical medium. Analysis of the section makes it possible to determine the main parameters of the triangular function when the linear parameters of the path ℓ_0, ℓ_x, ℓ_z are connected with the wavelength λ and the speed of the photon C_0 (C_{p0} and C_{z0}) through the period T

$$\ell_0 = \frac{1}{2}\lambda = \frac{1}{2}C_0 T \tag{6.168}$$

$$\ell_x = \frac{\ell_0}{n_0} = \frac{1}{2}\frac{\lambda}{n_0} = \frac{1}{2}C_{p0}T = \frac{1}{2}\frac{C_0 T}{n_0} \tag{6.169}$$

$$\ell_z = \ell_0\sqrt{1-\frac{1}{n_0^2}} = \frac{\lambda}{2}\sqrt{1-\frac{1}{n_0^2}} = \frac{C_0 T}{2}\sqrt{1-\frac{1}{n_0^2}} \tag{6.170}$$

From (6.170) we determine the amplitude ℓ_a of the triangular periodic function with ($\ell_a = 0.5\ell_z$)

$$\ell_a = \frac{1}{2}\ell_z = \frac{\ell_0}{2}\sqrt{1-\frac{1}{n_0^2}} = \frac{\lambda}{4}\sqrt{1-\frac{1}{n_0^2}} = \frac{C_0 T}{4}\sqrt{1-\frac{1}{n_0^2}} \tag{6.171}$$

Thus, if we start with the vector diagram (Fig. 6.13) of the photon, then its movement in the optical medium should be determined by the linear–broken triangular trajectory (Fig. 6.14 and 6.15). It would appear that this behaviour of the photon is fully understandable because it does not have any gravitational mass. On the other hand, the movement of the photon in the optical medium is a wave periodic process which should be harmonised to some extent, taking into account that this possibility is offered by the form of writing the complex speed (6.162) of the photon in the optical medium.

6.9. Wave trajectory of the photon in the optical medium

The photon is a unique particle with no gravitational mass. This complicates search for the equation of dynamics of the photon in the classic form in which the acceleration of the particle is determined by the force of the effect and mass of the particle. It would appear that the absence of mass in the photon would enable us to regard the photon as an inertialess particle.

In this case, moving along the linear-broken triangular trajectory (Fig. 6.14), the photon in the areas of breaks in the trajectory should be subjected to colossal acceleration with a sharp change of the direction of movement. However, this contradicts the constancy of the speed C_0 (6.161) of the photon in the quantised medium which can be fulfilled only if the trajectory of the photon has smoother transitions in contrast to the broken curve.

In fact, the speed of the photon C_0 is determined by the first derivative along the path ℓ_0 with respect to time t and is a constant quantity (6.161)

$$\frac{d\ell_0}{dt} = C_0 = \text{const} \tag{6.172}$$

We determine the acceleration of the photon as the second derivative along the path and the first derivative with respect to speed

$$\frac{d^2\ell_0}{dt^2} = \frac{dC_0}{dt} = 0 \tag{6.173}$$

The condition (6.172) of the constancy of the photon speed determines the new condition (6.173) according to which the photon cannot be accelerated. This means that the photon should move along a straight line. This is accurate from the viewpoint of classic mechanics, but the photon does not have a mass and is a relativistic wave particle travelling at the speed of light C_0 in the quantised medium. Consequently, it can be assumed that the classic equations (6.172) and (6.173) hold only for the modulus of the photon speed C_0. Taking into account that the photon speed C_0 is a vector whose direction

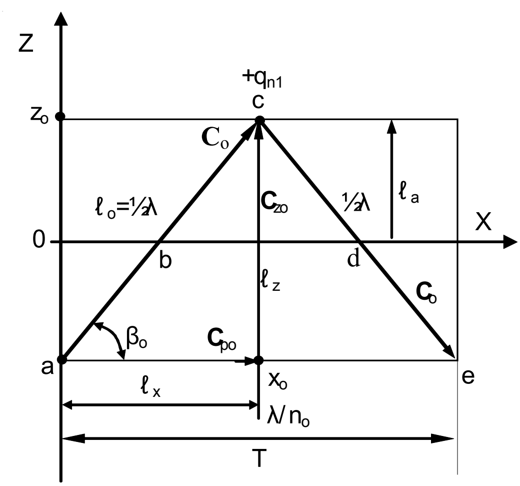

Fig. 6.15. Section of the period T of the linear–broken trajectory of the photon in the form of the triangular function in the optical medium.

can change, ensuring the constancy of the modulus of the speed of light C_0 (6.172), the equation of trajectory of movement of the photon in the optical medium can become a wave equation.

For the photon to move by wavy motion in the optical medium it is necessary to select the periodic function which would satisfy the condition of periodicity of the triangular function (Fig. 6.14) and the condition of constancy of the modulus of the speed of light C_0 (6.172). Therefore, it is rational to present the triangular periodic function $f(x)$ in the form of a Fourier series, with the expansion formula of the series known in electrodynamics [13]

$$f(x) = -\frac{8}{\pi^2}\ell_a\left[\cos\left(2\pi n_0\frac{x}{\lambda}\right) - \frac{1}{9}\left(3\cdot 2\pi n_0\frac{x}{\lambda}\right) + \frac{1}{25}\left(5\cdot 2\pi n_0\frac{x}{\lambda}\right) - \ldots\right] \quad (6.174)$$

Function $f(x)$ (6.173) is connected with the initial conditions in Fig. 6.14. Since the triangular periodic function $f(x)$ (6.174) is symmetric in relation to the X axis, it is represented by even harmonics. Naturally, in this case it is interesting to consider the first harmonics $f_1(x)$ whose wavelength and, appropriately, the frequency coincides with the wavelength λ and frequency of the electromagnetic field of the photon

$$f_1(x) = -\frac{8}{\pi^2}\ell_a\cos\left(2\pi n_0\frac{x}{\lambda}\right) \quad (6.175)$$

Into (6.175) we substitute the value of the amplitude ℓ_a (6.171)

$$f_1(x) = -\frac{2}{\pi^2}\lambda\sqrt{1-\frac{1}{n_0^2}}\cos\left(2\pi n_0\frac{x}{\lambda}\right) \quad (6.176)$$

Function $f_1(x)$ (6.176) can describe the wave trajectory of the photon on the condition that the path of the photon along the arc of the wave trajectory is equal to the path along a straight line ℓ_0 (Fig. 6.15). In this case, the parameters of the wave trajectory determine the equivalent refraction index n_0 (6.155) of the optical medium, as in the case of movement of the photon along a triangular trajectory. For this purpose, we determine the length of the arc $\ell_{1\lambda}$ of the cosine function $f_1(x)$ (6.176) by the well-known integral in the range from 0 to 1/2 λ/n_0

$$\ell_{1\lambda} = \int_0^{\lambda/2n_o}\sqrt{1+\left(\frac{df_1(x)}{dx}\right)^2}\,dx \quad (6.177)$$

Integral (6.177) includes the first derivative $f_1'(x)$ from $f_1(x)$ (6.176)

$$f_1'(x) = \frac{df_1(x)}{dx} = \frac{4}{\pi}\sqrt{n_0^2 - 1}\cdot\sin\left(2\pi n_0 \frac{x}{\lambda}\right) \quad (6.178)$$

If we substitute (6.178) into (6.177), the given integral still has no analytical solution. Therefore, it is rational to carry out numerical integration, dividing the arc of the cosine function $f_1(x)$ (6.176) into sections which can be replaced by straight lines. The summation of these lines gives the approximate value of the required length of the arc $\ell_{1\lambda}$.

For numerical solution of the integral (6.177) it is necessary to define specific conditions, continuing analysis of the behaviour of the photon, for example, of a red light with λ = 630 nm during its movement in a water medium with the refractive index n_0 = 1.33. Substituting these parameters into (6.171) we determine the amplitude ℓ_a of the triangular periodic function

$$\ell_a = \frac{\lambda}{4}\sqrt{1 - \frac{1}{n_0^2}} = 1.04\cdot 10^{-5}\,\mathrm{m} \quad (6.179)$$

The required length $\ell_{1\lambda}$ (6.177) of the first harmonics should be compared with the length ℓ_0 (6.168) of the side of the triangle of the triangular function, if the photon moves along the linear–broken trajectory in the optical medium

$$\ell_0 = \frac{1}{2}\lambda = 3.15\cdot 10^{-5}\,\mathrm{m} \quad (6.180)$$

Further, we determine the amplitude ℓ_{a1} of the first harmonics from (6.176)

$$\ell_{a1} = \frac{2}{\pi^2}\lambda\sqrt{1 - \frac{1}{n_0^2}} = 0.843\cdot 10^{-5}\,\mathrm{m} \quad (6.181)$$

The ratio of the amplitudes ℓ_{a1} (6.181) and ℓ_a (6.179) is equal to $8/\pi^2$

$$\frac{\ell_{a1}}{\ell_a} = \frac{8}{\pi^2} = 0.81 \quad (6.182)$$

Substituting the numerical value of the amplitude ℓ_{a1} (6.181) into (6.176), we consider the first harmonics in the range $x = 1/2\lambda/n_0$ (6.177)

$$f_1(x) = -\ell_{a1}\cos\left(2\pi n_0 \frac{x}{\lambda}\right) = -0.843\cdot 10^{-5}\cos\left(2\pi n_0 \frac{x}{\lambda}\right) \quad (6.183)$$

$$x = 0 \ldots \frac{\lambda}{2n_0} \approx 0 \ldots 2.4\cdot 10^{-5}\,\mathrm{m} \quad (6.184)$$

The interval along the axis X (6.184) is divided into 20 equal intervals Δx

$$\Delta x = \frac{\lambda}{40 n_0} \approx 0.12\cdot 10^{-5}\,\mathrm{m} \quad (6.185)$$

Table 6.3 gives the results of calculations of the values of the first harmonics $f_1(x)$ (6.183) on the Z axis with the intervals Δx (6.185).

Figure 6.16 shows the curve 1 (a_1–b–c_1) of the trajectory of the first harmonics $f_1(x)$ (6.183) of a red light photon with λ= 630 nm in movement in water with n_0 = 1.33. Curve 2 determines the possible trajectory of the photon in the section of the straight line (a–b–c) for the triangular periodic function (Fig. 6.14 and 6.15).

It is convenient to calculate the half $1/2\ell_{1\lambda}$ of the required arc length $\ell_{1\lambda}$ (6.177) of the curve 1 of the first harmonics $f_1(x)$ as the sum of its ten individual sections $\Delta\ell_{1\lambda}$ in equal 10 intervals Δx (6.185) for the intervals from 11 to 20 in the range 1, 2... 2, $4\cdot10^{-5}$m (or 90... 180°)

$$\tfrac{1}{2}\ell_{1\lambda} = \sum_{11}^{20} \Delta\ell_{1\lambda} = \sum_{11}^{20} \frac{\Delta x}{\cos\beta} \tag{6.186}$$

The angle β in (6.186) is the angle of inclination of the tangent to the curve 1 of the function $f_1(x)$ to the X axis (6.183). Angle β is determined from the first derivative $f_1'(x)$ (6.178) which determines the tangent of angle β at every point of the interval on the curve 1

$$\mathrm{tg}\beta = f_1'(x) = \frac{4}{\pi}\sqrt{n_0^2 - 1}\cdot\sin\left(2\pi n_0 \frac{x}{\lambda}\right) = 1.12\sin\left(2\pi n_0 \frac{x}{\lambda}\right) \tag{6.187}$$

Table 6.4 gives the results of calculations of angle β and individual sections $\Delta\ell_{1\lambda}$ of the curve 1 of the function $f_1(x)$ (6.183) in accordance with (6.186) in the range 1, 2... 2, $4\cdot10^{-5}$m (90...180°) for the intervals from 11 to 20.

The results of the calculations are used to determine the sum $1/2\ell_{1\lambda}$ (6.186) of the individual sections $\Delta\ell_{1\lambda}$ from the lower line of Table 6.4

$$\tfrac{1}{2}\ell_{1\lambda} = \sum_{11}^{20} \Delta\ell_{1\lambda} = 1.547\cdot10^{-5}\,\mathrm{m} \tag{6.188}$$

From (6.188) we determine the required length of the arc $\ell_{1\lambda}$ (6.177)

Table 6.3. Values of the first harmonics $f_1(x)$ (6.183)

Interval	1	2	3	4	5	6	7	8	9	10
x, 10^{-5}	0	0.12	0.24	0.36	0.48	0.60	0.72	0.84	0.96	1.08
Degree	0	9	18	27	36	45	54	63	72	81
$f_1(x)$, 10^{-5} m	–0.84	–0.83	–0.80	–0.75	–0.68	–0.59	–0.49	–0.38	–0.26	-0.13

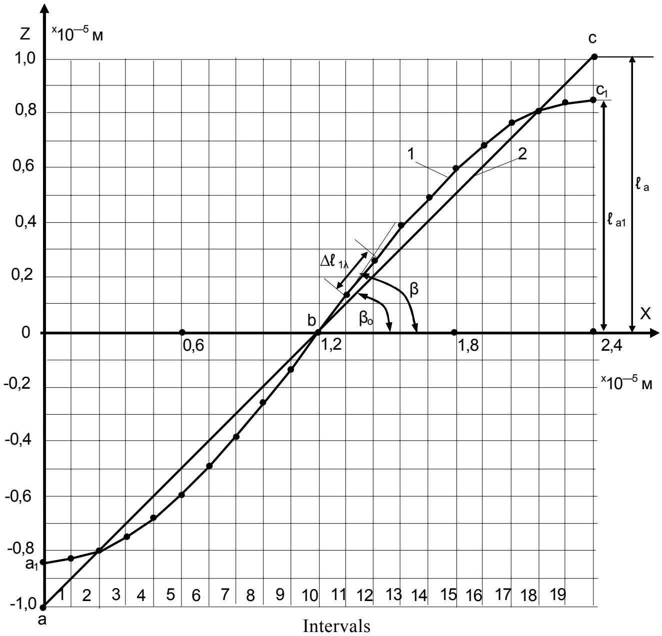

Fig. 6.16. Curve 1 of the trajectory of the first harmonics of the red light photon with λ = 630 nm in movement in water with n_0 = 1.33.

Table 6.4. Results of calculations of angle β and individual sections $\Delta\ell_{1\lambda}$ of the curve 1 of the function $f_1(x)$ (6.183)

Interval	11	12	13	14	15	16	17	18	19	20
x, 10–5 m	1.2	1.32	1.44	1.56	1.68	1.80	1.92	2.04	2.16	2.28
Degree	90	99	108	107	126	135	144	153	162	171
tg β	1.12	1.106	1.065	0.998	0.906	0.792	0.658	0.508	0.346	0.175
β, degree	48.2	47.9	46.8	44.9	42.2	38.4	33.4	27.0	19.1	9.94
$\Delta\ell_{1\lambda}$, 10–5 m	0.180	0.179	0.175	0.170	0.162	0.153	0.144	0.135	0.127	0.122

$$\ell_{1\lambda} = 2\sum_{11}^{20} \Delta\ell_{1\lambda} \approx 3.09 \cdot 10^{-5}\,\text{m} \tag{6.189}$$

The sought arc length $\ell_{1\lambda} \approx 3.09 \cdot 10^{-5}$ m (6.189) differs from the straight line $\ell_0 = 0.5\lambda = 3.15 \cdot 10^{-5}$ m (6.180) by only 1.9%. This is a fully acceptable result, taking into account the errors of the methods of approximate numerical calculations. More accurate results can be obtained by dividing the investigated function into a considerably larger number of intervals. To obtain complete agreement between $\ell_{1\lambda}$ and ℓ_0, the amplitude ℓ_{a1} (6.181) of the first harmonics should be slightly corrected.

Thus, the calculations show that for the optical photon, the arc length $\ell_{1\lambda}$ (6.180) of the first harmonics of the cosine function of its trajectory can be justifiably regarded as half length of the electromagnetic wave λ

$$\ell_{1\lambda} = \tfrac{1}{2}\lambda \qquad (6.190)$$

The simple relationship (6.190) changes in principle the current views regarding the movement of light in optical media. In fact, two waves permanently bonded together propagate in the optical medium:

1. The electromagnetic wave travels with the speed of light C_0 in the quantised medium whose carrier is the light-bearing medium.

2. The geometrical wave which propagates in the optical medium with the phase speed C_{p0} lower than the speed of light C_0 and which is synchronised with the electromagnetic wave, determining the wave trajectory of the photon in the optical medium.

The equation (6.190) describes the cosine trajectory of the photon in the form of the first harmonics $f_1(x)$ (6.176) of the triangular periodic function $f(x)$ (6.174), and the trajectory of the geometrical wave of the photon can be justifiably referred to as the wave trajectory.

Figure 6.17 ensures the wave trajectory of the photon in the optical medium. It should be mentioned that in movement of the photon with the period T is the ionisation plane of the photon rotate through the angle α_ω (6.140) which cannot be imaged in a flat projection.

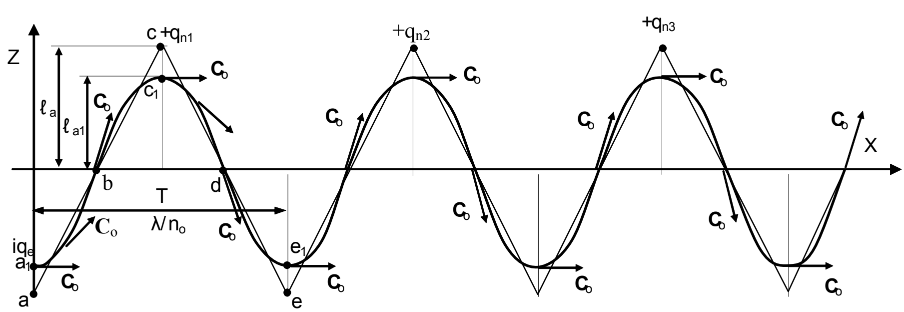

Fig. 6.17. Wave trajectory of the photon in the optical medium.

6.10. Forces acting on the photon in the optical medium

Let us consider the movement of the photon with the imaginary charge iq_e, starting at the moment when the photon is located at point (a_1) of the wave trajectory and starts capture of the atomic nucleus with the charge $+q_{n1}$ which is situated at the tip of the triangle at the point (c) (Fig. 6.16 and 6.17). We determine the maximum distance $r_{\max}$ of the start of capture of the nucleus by the photon as the distance between the charges iq_e and $+q_{n1}$ of the straight line $(a_1 - c)$

$$r_{\max} = \sqrt{(\ell_a + \ell_{a1})^2 + \left(\frac{\lambda}{2n_0}\right)^2} = \sqrt{\ell_a^2 + 2\ell_a \ell_{a1} + \ell_{a1}^2 + \frac{\lambda^2}{4n_0^2}} \quad (6.191)$$

Into (6.191) we substitute the amplitude ℓ_a (6.179) and ℓ_{a1} (6.181)

$$r_{\max} = \lambda\sqrt{\left(\frac{1}{16} + \frac{1}{\pi^2} + \frac{4}{\pi^4}\right)\left(1 - \frac{1}{n_0^2}\right) + \frac{1}{4n_0^2}} \approx \frac{\lambda}{n_0}\sqrt{0.21n_0^2 + 0.04}$$

$$r_{\max} \approx \frac{\lambda}{n_0}\sqrt{0.21n_0^2 + 0.04} \approx 0.46\lambda < 0.5\lambda \quad (6.192)$$

Equation (6.192) shows that capture of the atomic nucleus by the photon starts at distance $r_{\max}$ (6.192) smaller than half the wavelength, i.e., $r_{\max} < 0.5\lambda$. This is a very important moment, taking into account the fact that the effect of the imaginary electrical charge iq_e (6.118) of the photon operates at distances shorter than half the wavelength, i.e. $r \leq 0.5\lambda$

$$iq_e = (-e)\sqrt{2}\frac{\lambda_e}{\lambda}\sin\left(\frac{2\pi}{T}t\right)\sin\left(\frac{2\pi}{\lambda}r\right), \quad r \leq 0.5\lambda \quad (6.193)$$

In (6.193) the initial conditions are linked to Fig. 6.17. Therefore, the charge $(-e)$ in (6.193) has the minus sign. This ensures mutual attraction of the charges iq_e and $+q_{n1}$ during the first half period.

Regardless of the fact that at the moment of time $t = 0$ the imaginary charge iq_e (6.193) is situated at the point (a_1) and its effect is still equal to 0, at $t > 0$ the charge iq_e starts to increase rapidly and is ready for capturing of the atomic nucleus because $r_{\max} \approx 0.46\lambda < 0.5\lambda$ (6.192). In accordance with (6.193), the maximum effect $iq_{e\max}$ of the charge iq_e (6.193) is observed at the point (b) at $t = ¼T$ and $r = ¼\lambda$

$$iq_{e\max} = (-e)\sqrt{2}\frac{\lambda_e}{\lambda} \quad (6.194)$$

Further, the effect of the imaginary charge iq_e starts to weaken and at the point (c_1) it reaches zero. This corresponds to time $t = ½T$ and the maximum distance $r_{\min}$ between the charges iq_e and $+q_{n1}$

$$r_{\min} = \ell_a - \ell_{a1} = \lambda\left(\frac{1}{4} - \frac{2}{\pi^2}\right)\sqrt{1 - \frac{1}{n_0^2}} \approx 0.05\lambda\sqrt{1 - \frac{1}{n_0^2}} > 0 \quad (6.195)$$

When the photon passes through the point (c_1) of the trajectory at the time $t > ½T$, then in accordance with (6.193) the polarity of the imaginary charge iq_e (6.193) changes from negative to positive and the photon starts to be repulsed from the charge $+q_{n1}$ of the atomic nucleus. At point (d) the repulsion reaches the maximum value and also the value of the charge iq_{emax} (6.194), although it has the positive sign.

At the point (e_1) for $t = T$, the value of the charge iq_e (6.193) is equal to 0. At $t > T$ the second period starts with the capture of the atomic nucleus with the charge $+q_{n2}$, cyclically repeating the first period and determining the movement of the photon along the wave trajectory in all consecutive periods with capture of the atomic nucleus.

Of special interest is the determination of the force $\mathbf{F}_\text{v}$ of the interaction of the charges iq_e and $+q_{n1}$. It should be mentioned immediately that the interaction of the charge of the atomic nucleus $+q_n$ (6.144) with the imaginary charge iq_e (6.190) is not governed by the Coulomb law. This does not violate the fundamental laws in the area of the microworld of the elementary particles and it is the specific feature of interaction with the radial electrical field $\mathbf{E}_{rad}$ of the photon which is not spherical and is situated in the narrow plane of the rotor. The Coulomb law holds for spherical fields where the force of interaction between the charges decreases in inverse proportion to the distance.

To determine the force $\mathbf{F}_\text{v}$ of the interaction between the imaginary electrical charge of the photon and the charge of the atomic nucleus, it should be mentioned that the imaginary charge iq_e (6.193) is a variable charge with the change of both the magnitude and the sign with the frequency of the electromagnetic field of the photon. In addition, the effect of the charges is restricted by the photon diameter, i.e., does not extend to distances greater than ½λ from the centre of the photon. On approaching the charge iq_e its maximum value is obtained at a distance of ¼λ. At the distances ½λ and 0 from the photon centre the charge becomes equal to 0. The classic charges do not behave in this manner, as permitted by the specific features of the imaginary charge of the photon which takes into account the functional parameters of the radial electrical field $\mathbf{E}_{rad}$.

The special features of the imaginary photon charge differ from those of the field of the classic spherical electrical charge. The imaginary photon charge takes into account the functional parameters of the nonspherical radial electrical field $\mathbf{E}_{rad}$.

Since the functional dependence of the imaginary electrical charge iq_e (6.193) of the photon in time and in space is known, we can determine immediately the functional dependences of the radial electrical field $\mathbf{E}_{rad}$. For this purpose, we use the function $f(S)$ of the imaginary charge of the

iq_{er} (6.193) on the circular surface S of the rotor at the distance r from the centre of the photon in which the radial electrical field $\mathbf{E}_{rad}$ operates

$$\mathbf{E}_{rad} = \frac{1}{\varepsilon_0} \frac{iq_{er}}{\int f(S)dS} \tag{6.196}$$

In fact, the strength of any electrical field, including $\mathbf{E}_{rad}$ (6.196), is determined by the surface density of charges. For example, in the electron, the radial electrical field has spherical symmetry and is uniformly distributed on the sphere $S = 4\pi r^2$, determining the strength $E_e = e/4\pi\varepsilon_0 r^2$ of the electron field. In the photon, the radial electrical field of the rotor does not have spherical symmetry but the strength of its radial field is determined by the expression (6.196). The circular surface S of the photon rotor is determined as the function of r and thickness h_λ(6.56) of the rotor

$$S = 2\pi r h_\lambda \tag{6.197}$$

Taking into account (6.197), from (6.193) we immediately determine the distribution of the strength $\mathbf{E}_{\text{rad}}$ of the radial electrical field of the photon in time and in space

$$\mathbf{E}_{rad} = \frac{iq_e}{\varepsilon_0 S} = \frac{e}{2\pi\varepsilon_0 r h_\lambda} \frac{\lambda_e\sqrt{2}}{\lambda} \sin\left(\frac{2\pi}{T}t\right) \sin\left(\frac{2\pi}{\lambda}r\right) \cdot \mathbf{1}_r, \quad r \le \frac{\lambda}{2} \tag{6.198}$$

Equation (6.119) can be derived by analysing the distribution of the strength of the radial electrical field of the photon in time and in space. However, an interesting feature of (6.198) is that it is connected with the imaginary charge of the photon and determined by the elementary electrical charge e.

Knowing the function of strength $\mathbf{E}_{rad}$ (6.198) we can determine the force $\mathbf{F}_\text{v}$, acting on the photon from the side of the electrical charge of the nucleus of the atom of the molecular network (lattice) of the optical medium, captured by the radial electrical field $\mathbf{E}_{rad}$ of the electrical charge $+q_n$

$$\mathbf{F}_\text{v} = q_n \mathbf{E}_{rad} = \frac{eq_n}{2\pi\varepsilon_0 r h_\lambda} \frac{\lambda_e\sqrt{2}}{\lambda} \sin\left(\frac{2\pi}{T}t\right) \left|\sin\left(\frac{2\pi}{\lambda}r\right)\right| \cdot \mathbf{1}_r, \quad r \le \frac{\lambda}{2} \tag{6.199}$$

The function of the force $\mathbf{F}_\text{v}$ (6.199) is alternating only with respect to time t (or wavelength λ) and not with respect to the distance r between the charges iq_e and $+q_n$. Therefore, in equation (6.199) the functional dependence of the force $\mathbf{F}_\text{v}$ on distance r between the charges is described by the modulus $|\sin(2\pi r/\lambda)|$. The distance r is determined by the radius-vector $\mathbf{r}$ which coincides with the direction of the unit vector $\mathbf{1}_r$ in (6.199). The function of the distance $r(x)$ between the charges iq_e and $+q_n$ is determined by the longitudinal x_r and transverse z_r components of the radius-vector **r**

$$r = \sqrt{x_r^2 + z_r^2} \tag{6.200}$$

$$x_r = \frac{\lambda}{2n_0} - x \tag{6.201}$$

The transverse component z_r is determined from $f_1(x)$ (6.175) and the amplitude ℓ_a (6.173)

$$z_r = \ell_a + f_1(x) = \frac{\lambda}{4}\sqrt{1 - \frac{1}{n_0^2}}\left[1 + \frac{8}{\pi^2}\cos\left(2\pi n_0 \frac{x}{\lambda}\right)\right] \tag{6.202}$$

Substituting (6.201) and (6.202) into (6.200), we obtain the function $r(x)$

$$r(x) = \sqrt{\frac{1}{n_0^2}\left(\frac{1}{2}\lambda - x\right)^2 + \frac{\lambda^2}{16}\left(1 - \frac{1}{n_0^2}\right)\left[1 + \frac{8}{\pi^2}\cos\left(2\pi n_0 \frac{x}{\lambda}\right)\right]^2} \tag{6.203}$$

From (6.202) and (6.201) we determine the tangent of the angle of inclination α_r of the force vector $\mathbf{F}_v$ (6.199) of the X axis and the angle α_r itself as the function of x

$$\mathrm{tg}\,\alpha_r = \frac{z_r}{x_r} = \frac{\frac{\lambda}{4}\sqrt{1 - \frac{1}{n_0^2}}\left[1 + \frac{8}{\pi^2}\cos\left(2\pi n_0 \frac{x}{\lambda}\right)\right]}{\frac{\lambda}{2n_0} - x} \tag{6.204}$$

$$\alpha_r = \mathrm{arctg}\frac{\frac{\lambda}{4}\sqrt{1 - \frac{1}{n_0^2}}\left[1 + \frac{8}{\pi^2}\cos\left(2\pi n_0 \frac{x}{\lambda}\right)\right]}{\frac{\lambda}{2n_0} - x} \tag{6.205}$$

Knowing the angle α_r (6.205), we express the longitudinal $\mathbf{F}_{vx}$ and transverse $\mathbf{F}_{vz}$ components of the force $\mathbf{F}_v$ (6.199) (where $\mathbf{1}_x$ and $\mathbf{1}_z$ are the unit vectors on the axes X and Z, respectively)

$$\mathbf{F}_{vx} = F_v \cos\alpha_r \cdot \mathbf{1}_x \tag{6.206}$$

$$\mathbf{F}_{vz} = F_v \sin\alpha_r \cdot \mathbf{1}_z \tag{6.207}$$

To determine the components $\mathbf{F}_{vx}$ and $\mathbf{F}_{vz}$ of the force $\mathbf{F}_v$, it is necessary to determine in (6.199) the function of time t with respect to x, i.e. $t(x)$. If the movement of the photon were determined by the linear–broken trajectory of the described triangular periodic function $f(x)$ (6.174), time t would be a linear function of x (Fig. 6.14)

$$t(x) = \frac{\ell_0}{C_0} = \frac{x}{C_{p0}} = \frac{n_0}{C_0}x \tag{6.208}$$

In fact, as shown previously, the photon moves along a wave-shaped trajectory described by the first harmonics $f_1(x)$ (6.176) of the periodic function in accordance with the cosine law. This non-linear function, derivative with respect to time t in the section of length $\ell_{1\lambda}$ (6.177) determines the absolute speed of the photon C_0

$$\mathrm{C}_0 = \frac{d\ell_{1\lambda}}{dt} \tag{6.209}$$

The element of length $d\ell_{1\lambda}$ (6.209) of the curvilinear trajectory of the photon is expressed through the longitudinal x and transverse z components

$$d\ell_{1\lambda} = \sqrt{dx^2 + dz^2} = \sqrt{1 + \left(\frac{dz}{dx}\right)^2}\,dx \tag{6.210}$$

We substitute (6.210) into (6.209) and after dividing the variables we can write the integral for time t as the function of x

$$t = \frac{1}{C_0}\int\sqrt{1 + \left(\frac{dz}{dx}\right)^2}\,dx \tag{6.211}$$

Equation (6.211) includes the first derivative $f_1'(x)$ (6.178) of the function $f_1(x)$ (6.176) of the cosine trajectory of the photon, determining the tangent of the angle of inclination β of the tangen to the X axis

$$\frac{dz}{dx} = \frac{df_1(x)}{dx} = \mathrm{tg}\beta = \frac{4}{\pi}\sqrt{n_0^2 - 1}\cdot\sin\left(2\pi n_0\frac{x}{\lambda}\right) \tag{6.212}$$

$$\beta = \mathrm{arctg}\left[\frac{4}{\pi}\sqrt{n_0^2 - 1}\cdot\sin\left(2\pi n_0\frac{x}{\lambda}\right)\right] \tag{6.213}$$

Even if we substitute (6.212) into (6.211), the resultant integral, as mentioned, does not have any analytical solution. The numerical solution of the identical integrals (6.177) shows that the length of the arc $\ell_{1\lambda}$ (6.190) of the first harmonics of the cosine function of the trajectory of the photon within the integration range $x = \lambda/2n_0$ is equal to half the length of the electromagnetic wave λ

$$\ell_{1\lambda} = \tfrac{1}{2}\lambda \tag{6.214}$$

Substituting the solution of (6.214) into (6.211) and taking (6.212) into account, we obtain

$$t = \frac{1}{C_0} \int_0^{\lambda/2n_o} \sqrt{1 + \left(\frac{dz}{dx}\right)^2} dx = \frac{1}{2}\frac{\lambda}{C_0} = \frac{1}{2}T \tag{6.215}$$

The solution (6.250) confirms that the duration of the half period of the photon in transition from the linear–broken trajectory of the triangular function to its first harmonics remains unchanged. This is important because there are reference points on the trajectory of the photon at which the wave parameters do not change. However, the integral (6.250) does not make it possible to determine the required function $t(x)$ inside the half period of the photon.

This exhausts the mathematical possibilities of the analytical solution and only numerical methods remain. In any case, the proposed method can be used to determine the forces acting on the photon in the optical medium and obtain, in the final analysis, a dynamic equation of the motion of the photon. Analysis of this equation is outside the framework of this book.

6.11. Refractive index of the optical medium

The movement of a photon along a wave-shaped trajectory, which is described by the first harmonics of the triangular function, satisfies the condition of the constancy of the speed of light in the quantised medium. However, the angle of inclination of the tangent to the harmonic wave-shaped trajectory, which determines the refractive index of the medium, is a variable value and it is necessary to prove that the effectiveness of the optical medium n_0 is an averaged-out parameter. For this purpose, we again describe the absolute speed of the photon $\mathbf{C}_0$ as the vector sum of its longitudinal $\mathbf{C}_{p0}$ component along the X axis and the transverse components $\mathbf{C}_{z0}$ (6.156) along the Z axis

$$\mathbf{C}_0 = \mathbf{C}_{p0} + \mathbf{C}_{z0} \tag{6.216}$$

The values of the components $\mathbf{C}_{p0}$ and $\mathbf{C}_{z0}$ of the absolute speed $\mathbf{C}_0$ (6.216) can be written conveniently by means of the function of angle β (6.113), showing that the components $\mathbf{C}_{p0}$ and $\mathbf{C}_{z0}$ also represent the functional dependences on x on the wavelength λ during the period T

$$\begin{cases} \mathbf{C}_{p0} = C_0 \cos\beta \cdot \mathbf{1}_x = C_0 \cos\left\{ \operatorname{arctg}\left[\frac{4}{\pi}\sqrt{n_0^2 - 1} \cdot \sin\left(2\pi n_0 \frac{x}{\lambda}\right)\right]\right\} \cdot \mathbf{1}_x \\ \mathbf{C}_{z0} = C_0 \sin\beta \cdot \mathbf{1}_z = C_0 \sin\left\{ \operatorname{arctg}\left[\frac{4}{\pi}\sqrt{n_0^2 - 1} \cdot \sin\left(2\pi n_0 \frac{x}{\lambda}\right)\right]\right\} \cdot \mathbf{1}_z \end{cases} \tag{6.217}$$

Figure 6.18 shows the vector diagram of the variation of the longitudinal $\mathbf{C}_{p0}$ and transverse $\mathbf{C}_{z0}$ component of the absolute speed of the photon $\mathbf{C}_0$ in the optical medium in accordance with (6.217) at the wavelength λ during the period T, when the vector $\mathbf{C}_0$ changes its angle of inclination β (6.213) from 0 to $\pm\,\beta_{\max}$ at the points (b) and (d) on the trajectory (Fig. 6.17)

$$\beta_{\max} = \pm \mathrm{arctg}\left(\frac{4}{\pi}\sqrt{n_0^2 - 1} \right) \tag{6.218}$$

The vector diagram in Fig. 6.18 differs in principle from the vector diagram in Fig. 6.13 where the longitudinal $\mathbf{C}_{p0}$ and transverse $\mathbf{C}_{z0}$ components of the speed $\mathbf{C}_0$ are connected with the angle β_0 (6.299) which is regarded as a constant

$$\beta_0 = \mathrm{arctg}\sqrt{n_0^2 - 1} \tag{6.219}$$

$$\mathrm{tg}\,\beta_0 = \sqrt{n_0^2 - 1} \tag{6.220}$$

Angle $\beta_{\max}$ (6.218) is larger than angle β_0 (6.219)

$$\frac{\mathrm{tg}\,\beta_{\max}}{\mathrm{tg}\,\beta_0} = \frac{4}{\pi} = 1.27 \tag{6.221}$$

As indicated by (6.219) and (6.220), angle β_0 is equivalent to the refractive index n_0 which is also a constant. However, investigations show that during the period angle β varies from 0 to $\pm\,\beta_{\max}$ (6.218). This means that the refractive index n_0 of the optical medium changes in value during the period. Therefore, it can be assumed that the refractive index n_0 of the medium is an averaged-out parameter.

To prove this, it is necessary to find the mean value $\mathrm{tg}_{av}\beta$ of the tangent of angle β (6.230) and compare with $\mathrm{tg}\beta_0$ (6.229). However, $\mathrm{tg}\beta_0$ is determined by the linear–broken trajectory of the photon with the amplitude

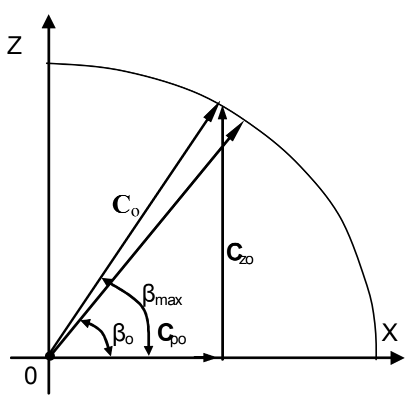

Fig. 6.18. Vector diagram of the longitudinal $\mathbf{C}_{p0}$ and transverse $\mathbf{C}_{z0}$ components of the absolute speed of the photon $\mathbf{C}_0$ in the optical medium.

ℓ_a (6.171) of the triangular function (Fig. 6.15). Amplitude ℓ_{a1} (6.181) of the cosine trajectory of the photon is determined by the amplitude of the first harmonics of the triangular function, determining the ratio of the amplitude (6.182)

$$\frac{\ell_{a1}}{\ell_a} = \frac{8}{\pi^2} \tag{6.222}$$

Evidently, as regards the averaged-out parameters of the linear and non-linear functions it is necessary to find out whether they can be reduced to the form suitable for comparison equating their amplitudes. In fact, the compared value of $\text{tg}\beta_0$ is determined by the amplitude ℓ_a, which differs from the amplitude ℓ_{a1} of the cosine function for the sought mean value $\text{tg}_{av}\beta$. Therefore, we reduce the amplitudes of these functions to the single value taking into account (6.222). The mean value of $\text{tg}_{av}\beta$ is equal to $\text{tg}\beta_0$ (6.220) only in this case.

$$\begin{aligned} \text{tg}_{av}\beta &= \frac{\ell_a}{\ell_{1a}} \frac{4n_0}{\lambda} \int_0^{\lambda/4n_0} \frac{4}{\pi}\sqrt{n_0^2 - 1} \cdot \sin\left(2\pi n_0 \frac{x}{\lambda}\right) dx = \\ &= \frac{\ell_a}{\ell_{1a}} \frac{8}{\pi^2} \sqrt{n_0^2 - 1} = \sqrt{n_0^2 - 1} \end{aligned} \tag{6.223}$$

$$\text{tg}_{av}\beta = \text{tg}\beta_0 = \sqrt{n_0^2 - 1} \tag{6.224}$$

Equation (6.224) shows that the refractive index n_0 of the optical medium is the averaged parameter $\text{tg}_{av}\beta$ for the photon travelling along the wave-shaped trajectory in a stationary optical medium

$$n_0 = \sqrt{\text{tg}_{av}^2\beta + 1} \tag{6.225}$$

When the optical medium also moves, as in the Fizo experiment, the refractive index of the medium changes. This problem has been examined in considerable detail in [2] when proving the reality of the light-bearing medium. It should be added that from the viewpoint of electrodynamics, the partial carrying away of the light by the moving optical medium can be regarded as an asynchronous effect when the field of the moving lattice of the optical medium passes with a certain gliding in relation to the moving photon. Naturally, the refractive index n_0 of the optical medium depends on the frequency of the electromagnetic field of the photon and is determined by the lattice parameters of the optical medium in which perturbations depend mainly on temperature and pressure. However, the investigation of these relationships is outside the framework of the present book. Naturally, knowledge of the structure of the photon and of the reasons for the decrease of the photon speed in optical media have the controlling effect on the change of the old considerations regarding the electrodynamics of the moving media [14].

Thus, the investigation show finally that without analysis of the parameters of the light-bearing medium it is not possible to examine the nature and structure of the photon as the particle-wave which is the integral part of the quantised space-time.

Conclusions

1. The new fundamental discoveries of the space-time quantum (quanton) and of the superstrong electromagnetic interaction (SEI) open a new era in the quantum theory, establishing the deterministic nature of the quantum mechanics and electrodynamics. Most importantly, the new fundamental discoveries explain the reasons for quantum phenomena hidden in the quantum nature of space-time. It may be confirmed that there are no non-quantised objects in the nature. The quantised objects include the radiation quantum (photon). Previously, it was assumed that energy quantisation takes place by means of radiation quantum. Now we have established the quantisation of the very radiation quantum by the quantons (space-time quanta) where the radiation quantum (photon) represents a secondary wave formation in the quantised space-time.

2. The new fundamental discoveries have made it possible to apply the classic concept in the quantum theory and, at the same time, describe for the first time the nature and structure of the photon whose parameters can be calculated, bypassing the static wave function. It has been established that the photon is a two-rotor relativistic particle whose electrical and magnetic rotors exist simultaneously and are located in the orthogonal polarisation planes. The intersection of the polarisation planes forms the main axis of the photon around which polarisation planes can rotate. The main axis of the photon is directed along the vector of the speed of movement of the photon in the quantised medium. In this form, the photon is a wave-particle, some concentrated bunch of electromagnetic energy of the quantised space-time, travelling at the speed of light.

3. The variable electromagnetic field of the photon satisfies the two-rotor Maxwell equation and the classic wave equation. The calculation parameters of the photon were determined for the first time: the strength of the electrical and magnetic fields in the photon rotors, the density of the electrical and magnetic bias currents, the currents themselves, and many other parameters which could not previously be calculated.

4. It has been established that the deceleration of light in the optical medium is determined by the wave trajectory of the photon as a result of the probability capture by the photon of the atomic centres of the lattice of the optical medium when the vector of the photon speed in the quantised medium does not coincide with the vector of speed in the optical medium. In fact, two waves propagate in the optical medium and these waves are permanently connected together:

a) the electromagnetic wave which travels with the speed of light $\mathbf{C}_0$ in the quantised medium and is transferred by the light-bearing medium;

b) the geometrical wave which propagates in the optical medium with phase speed $\mathbf{C}_{p0}$ lower than the speed of light $\mathbf{C}_0$, which is synchronised with the electromagnetic wave and determines the wave trajectory of the photon in the optical medium.

5. It has been shown that the wave trajectory of the photon in the optical medium can be represented by the first harmonics of the triangular periodic function. The condition of movement of the photon along the wave trajectory is the constancy of the speed of light in the quantised medium. In this case, the imaginary motion along a straight line in the optical medium in the same period of time as in the case of the wave trajectory is regarded as the deceleration of light in the optical medium. The calculations show that the refractive index of the light by the optical medium can be regarded as the averaged parameter of the medium in movement of the photon along the wavy trajectory.

References for chapter 6

1. Leonov V.S., Electromagnetic nature and structure of space vacuum, Chapter 2 of this book.
2. Leonov V.S., Unification of magnetism and gravitation. Antigravitation, Chapter 3 of this book.
3. Einstein A., Heuristic viewpoint regarding the formation and transformation of light. Collected studies, volume 3, Nauka, Moscow, 1966, 92–107.
4. Einstein A., Theory of formation and absorption of light, Collected studies, volume 3, Nauka, Moscow, 1966, 128–133.
5. Einstein A., Notes on quantum theory, Collected studies, volume 3, Nauka, Moscow, 1966, 528–530.
6. Einstein A., Quantum mechanics and reality, Collected studies, volume 3, Nauka, Moscow, 1966, 612–616.
7. Berestetskii V.B., et al., Theoretical physics, vol. 4, Quantum electrodynamics, Chapter 1, Photon, Nauka, Moscow, 1989, 19–50.
8. Leonov V.S., Spherical invariance in construction of of an absolute cosmological model, in: Four lectures on the theory of the elastic quantised medium (EQM), St. Peterburg, 2000, 26–38.
9. Landau L. and Lifshits E.M., Field theory, Nauka, Moscow, 1967.

10. Rekami E., Theory of relativity and its generalisations, in: Astrophysics, quanta and theory of relativity, Mir, Moscow, 1982, 63–87.
11. Leonov V.S., Discovery of gravitational waves by Prof. Veinik, Agrokonsalt, Moscow, 2001.
12. Blokhintsev D.I., Fundamentals of quantum mechanics, GITTL, Moscow and Leningrad, 1949.
13. Bessonov L.A., Theoretical fundamentals of electrical engineering, Vysshaya shkola, Moscow, 1973.
14. Bolotovskii B.M. and Stolyarov S.N., Current state of electrodynamics of moving media (infinite media), Einstein Collection, Naula, Moscow, 1987, 179–275.