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To cite this article: Dmitri Yerchuck *et al* 2014 *J. Phys.: Conf. Ser.* **490** 012102

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Boson Model of Quantized EM-Field and Nature of Photons

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Abstract. The fundamental result, obtained by Dirac, that the dynamical system, which consists of the ensemble of identical bosons is equivalent to the dynamical system, which consists of the ensemble of oscillators, was used to show, that the presence of scalar charge function $\rho(\vec{r}, t)$ to be peer force characteristic of electromagnetic (EM) field along with vector force characteristics $\vec{E}(\vec{r}, t)$, $\vec{H}(\vec{r}, t)$, that was established earlier, agrees with charge neutrality of photons. The simplest analogue in its mathematical description in the physics of condensed matter is the chain of bosonic (spin $S = 1$) carbon atoms in *trans*-polyacetylene. It has been shown, that neutral photons are topological relativistic solitons with nonzero spin value, which is equal to $\frac{1}{2}$ instead of prevalent viewpoint, that the photons possess by spin $S = 1$. Naturally, they have nonzero size, that is, they cannot be considered to be point objects. At the same time, the main excitations in so called "doped" rest massless "boson-atomic" structure of EM-field will be charged spinless EM-solitons. It seems to be reasonable to suggest, that "doping" can be effective by propagation of EM-field in the medium like to rain-clouds, although detailed mechanism has to be additionally studied.

The representation of photons to be the result of spin-charge separation effect in rest massless "boson-atomic" structure of EM-field makes substantially more clear the nature of corpuscular-wave dualism.

1. Introduction

Earlier symmetry studies of Maxwell equations [1] gave new insight on the nature of electromagnetic (EM) field. The existence of dual symmetry of Maxwell equations, determined by dual transformations, established by Rainich [2] and additional dual symmetry, established in [1], determines the mathematical structure of the quantities incoming in Maxwell equations. They are quaternions and, consequently, Maxwellian EM-field has in general case quaternion structure. It consists of four independent field constituents, which differ each other by the parities under space inversion and time reversal. The presence along with 3-vector quaternion characteristics the independent scalar quaternion characteristics of EM-field [1] allowed to describe EM-field instead of unobservable vector and scalar potentials by observable electric field 4-vector-function with the components $E_\alpha(\vec{r}, t) = \{E_x(\vec{r}, t), E_y(\vec{r}, t), E_z(\vec{r}, t), i\frac{c\rho_e(\vec{r}, t)}{\lambda}\}$ and (or in the case of free EM-field) by means of magnetic field 4-vector-function $H_\mu(\vec{r}, t) = \{H_x(\vec{r}, t), H_y(\vec{r}, t), H_z(\vec{r}, t), i\frac{c\rho_m(\vec{r}, t)}{\lambda}\}$, where $ic\rho_e(\vec{r}, t)$, $ic\rho_m(\vec{r}, t)$ are the $j_4(\vec{r}, t)$ -components of 4-current density, corresponding to contribution of electric and magnetic components of charge



densities correspondingly, λ is conductivity, which for the case of EM-field propagation in vacuum is $\lambda_v = \frac{1}{120\pi} (Ohm)^{-1}$. The most actual for the tasks of modern theories of interaction of EM-field with matter, taking into account their practical application to nanoelectronics, spintronics and to a number of the other nanotechnology branches represents the quantum description of EM-field. The well known now simple formula $E = h\nu$, $h = const > 0$, proposed right at the beginning of the 20th century by Planck [4] and by Einstein [5] became epoch-making and a real symbol of the substantial progress in the science. The interpretation, given by Einstein, indicates straight on real existence of light quanta of frequency ν with the total energy E , which in its turn has led to a new understanding of the nature of the electromagnetic field. In fact it was the indication on oscillatory, that is discrete in space structure of EM-field, which in the same time is the set of physical objects strongly connected to some periodic with time period $T = 1/\nu$ process, being to be intrinsic for given objects, at that Lorentz invariant product ET is equal to h . Similar interpretation of De Broglie's relationship [6] leads to conclusion on quantum nature of the charges. Although there are the great achievements in quantum theory, the great challenge to give an adequate description of light quanta, which were called by Lewis photons [7], still has not brought satisfactory results in fact up to now. Even Einstein himself recognizes [8] in one's time, that the whole fifty years of conscious brooding have not brought me nearer to the answer to the question what are light quanta, and now, more than half a century later, theoretical physics still needs progress to present a satisfactory explanation of the photon nature and to propose its structure. We will show, that the quaternion structure of EM-field and the existence of the charge, being to be inherent scalar force characteristic of EM-field, allow to understand the nature of photons. Let us remark the following. On the one hand, the photons seem to be charge neutral particles, which is confirmed in a number of observations, including astronomic observations, and experiments on light absorption, transmission, reflection, Rayleigh and Raman scatterings and so on. On the other hand, the photons seem to be charged particles, which is confirmed, for example, by observations of zigzag-like light propagation between adjacent rainclouds during storm, since zigzag-like light propagation (forked lightning) in the same conditions (that is by the absence of lightning between the same rainclouds) does not takes place. The fact, that the appearance of forked lightning is connected with charge particles, was confirmed experimentally long time ago. Consequently, it is reasonable to suggest, that quantum structure of EM-field is responsible for lightning development and propagation, since the velocity of the process of lightning development and propagation is too much, in order to refer given effect the only to dielectric medium, in which any electrically conducting canals are absent. In its turn, it allows to suggest, that by EM-field propagation in rainclouds the charged photons, that is, the photons of the other kind in comparison with usual ones, can be created. It will be proved in given work. It is the aim of the work presented.

2. Results and Discussion

The fundamental result, obtained by Dirac, that dynamical system, which consists of the ensemble of identical bosons, is equivalent to dynamical system, which consists of the ensemble of oscillators, will be used to show, that the existence of the charge agrees with charge neutrality of photons. The simplest analogue in the physics of condensed matter of the system of interacting $S = 1$ bosons is carbon. So we come to the model of linearly polarized EM-field to be the chain of bosons, which is like in its mathematical description to the chain of carbon atoms in *trans*-polyacetylene (t-PA), at that both in "atomic" and "electronic" structure. One-dimensionality of the task can be argued in the following way. Since for the description of EM-field instead of unobservable vector and scalar potentials the 4-vector of electrical and/or magnetic field strength can be used, then, to describe linearly polarized EM-field in Euclidian space R_3 it is sufficient to specify the propagation direction, that is vector \vec{k} and to define \vec{E} . Given vectors determine the plane, in which a frame of reference with z -axis along the propagation

direction and orthogonal to it x -axis can be set. Taking into account the homogeneity of Minkowski space R_4 and homogeneity of free EM-field in it, free EM-field can be modelled by the set of noninteracting (or weak interacting) between themselves "boson-atomic" chains, similarly to those ones in many carbon-based systems. What concerned the "atomic" structure, we have to include the contribution of vacuum fluctuations, which presents in oscillator task and which is absent in the case of boson task. The presence of charge, being to be scalar characteristic of EM-field, gives the possibility to model "electronic" structure of equivalent boson chain like to t-PA electronic structure, that is consisting of " σ -subsystem" and " π -subsystem". It becomes to be understandable, if to take into account, that charge space distribution is directly connected with \vec{E} space distribution. In other words the presence of E_z -component will determine the appearance of EM-field charge " σ -subsystem", while E_x -component will determine the appearance of EM-field charge " π -subsystem", at that, like to t-PA, its distribution in space R_3 will be twice degenerated. Given conclusion can be argued on the basis quaternion structure of EM-field in the following way. E_x -polar component by EM-field propagation every other half-period alters its sign, at the same time E_x -axial component does not alters its sign, which is equivalent to appearance of alternating single-double interbosonic " π -bonds" in EM-field charge " π -subsystem", at that two configuration - single-double and double-single are topologically equivalent. Consequently we come to conclusion, that the interaction between equivalent to oscillators "bosonic atoms" can be described in the frames of 1D Fermi gas model in zero-th order approximation or in the frames of 1D Fermi liquid model in the first order approximation. Mathematical description in zero-th order approximation will be similar to well known Su-Schrieffer-Heeger (SSH) model of organic conductors with some corrections, concerning two branch of quasiparticles, given in [3]. Fermi liquid model for 1D case will represent the generalization of SSH-model and it will be considered in details in applicability to EM-field description. The concept of quantum 1D Fermi liquid for description of 1D correlated electronic systems was recovered in [15]. It has topological soliton origin in distinction from well known spinon-holon spin-charge separation effect in Luttinger liquids. Analogous model will be developed in given paper for description of propagation of quantized EM-field. We will start from Hamiltonian

$$\hat{\mathcal{H}}(u) = \hat{\mathcal{H}}_0(u) + \hat{\mathcal{H}}_{\pi,t}(u) + \hat{\mathcal{H}}_{\pi,u}(u). \quad (1)$$

Like to works [13], [14] we will consider Born-Oppenheimer approximation. The first term in (1) is

$$\hat{\mathcal{H}}_0(u) = \sum_m \sum_s (E_m^k \hat{a}_{m,s}^+ \hat{a}_{m,s} + K u_m^2 \hat{a}_{m,s}^+ \hat{a}_{m,s}) \quad (2)$$

is the operator of kinetic energy of "boson atom" motion (the first term), and the operator of the σ -bonding energy the second term, K is effective σ -bonds spring constant, u_m is configuration coordinate for m -th "boson atom", which corresponds to translation of m -th "boson atom" along the symmetry axis z of the chain, $m = \overline{1, N}$, N is number of "boson atoms" in the chain, $m = \overline{1, N}$, $\hat{a}_{m,s}^+$, $\hat{a}_{m,s}$ are creation and annihilation operators of creation or annihilation of quasiparticle with spin projection s on the m -th chain site in " σ -subsystem". The second term in (1) is

$$\hat{\mathcal{H}}_{\pi,t}(u) = \sum_m \sum_s [t_0 (\hat{c}_{m+1,s}^+ \hat{c}_{m,s} + \hat{c}_{m,s}^+ \hat{c}_{m+1,s})]. \quad (3)$$

It is the resonance interaction (hopping interaction in tight-binding model approximation) of quasiparticles in " π -subsystem" of all charge system, which is considered to be Fermi liquid, and in which the only constant term in Taylor series expansion of resonance integral about the dimerized state is taking into account. Here $\hat{a}_{m,s}^+$, $\hat{a}_{m,s}$ are creation and annihilation operators

of creation or annihilation of quasiparticle with spin projection s on the m -th chain site in " π -subsystem". The third term in (1) is

$$\hat{\mathcal{H}}_{\pi,u}(u) = \sum_m \sum_s [(-1)^m 2\alpha_1 u (\hat{c}_{m+1,s}^+ \hat{c}_{m,s} + \hat{c}_{m,s}^+ \hat{c}_{m+1,s}) + (-1)^m 2\alpha_2 u \hat{c}_{m,s}^+ \hat{c}_{m+1,s}^+ \hat{c}_{m+1,s} \hat{c}_{m,s}]. \quad (4)$$

It represents correspondingly the terms, which are proportional to linear terms in Taylor series expansion about the dimerized state of the resonance interaction of quasiparticles in " π -subsystem" of charge system and potential energy of the pairwise interaction of quasiparticles in " π -subsystem" between themselves. It is taken into account, that in Born-Oppenheimer approximation in perfectly dimerized chain the coordinates $\{u_m\}$, $m = \overline{1, N}$, can be represented in the form $\{u_m\} = \{(-1)^m u\}$, where u is displacement amplitude, corresponding to minimum of ground state energy [13]. In result of solving of the task formulated with Hamiltonian (1) two values for the energy of quasiparticles were obtained, indicating on the possibility of formation of the quasiparticles in c -band and v -band of two kinds. They are

$$E_k^{(c)}(u) = \frac{Q^2 \Delta_k^2 - \epsilon_k^2}{\sqrt{\epsilon_k^2 + Q^2 \Delta_k^2}}, \quad (5)$$

$$E_k^{(v)}(u) = \frac{\epsilon_k^2 - Q^2 \Delta_k^2}{\sqrt{\epsilon_k^2 + Q^2 \Delta_k^2}}$$

and

$$E_k^{(c)}(u) = \sqrt{\epsilon_k^2 + Q^2 \Delta_k^2}, \quad (6)$$

$$E_k^{(v)}(u) = -\sqrt{\epsilon_k^2 + Q^2 \Delta_k^2},$$

where $\Delta_k = 4\alpha_1 u \sin ka$, $\epsilon_k = 2t_0 \cos ka$, the value for factor Q satisfies the equation

$$\left[1 + \frac{\alpha_2}{2\alpha_1} \sum_k \sum_s \frac{Q \Delta_k \sin ka}{\sqrt{\epsilon_k^2 + Q^2 \Delta_k^2}} (n_{k,s}^{(c)} - n_{k,s}^{(v)})\right] = Q, \quad (7)$$

where $n_{k,s}^{(c)}$ is eigenvalue of density operator of quasiparticles' number in c -band, $n_{k,s}^{(v)}$ is eigenvalue of density operator of quasiparticles' number in v -band. It is evident, that at $Q = 1$ in (5), (6) we have the case, equivalent to SSH-model. It can be realized, if $\frac{\alpha_2}{\alpha_1} \sum_k \sum_s \frac{1}{2} \frac{\Delta_k}{\sqrt{\epsilon_k^2 + \Delta_k^2}} \sin ka (n_{k,s}^{(c)} - n_{k,s}^{(v)}) \rightarrow 0$, which, in its turn, is realized, if $\alpha_2 \rightarrow 0$. Consequently, it seems to be interesting to consider the opposite case, when $|\frac{\alpha_2}{\alpha_1} \sum_k \sum_s \frac{1}{2} \frac{\Delta_k}{\sqrt{\epsilon_k^2 + \Delta_k^2}} \sin ka (n_{k,s}^{(c)} - n_{k,s}^{(v)})| \gg 1$. Passing on to continuum limit, in which $\sum_k \sum_s \rightarrow 2 \frac{Na}{\pi} \int_0^{\frac{\pi}{2a}}$, and assuming $n_{k,s}^{(v)} = 1$, $n_{k,s}^{(c)} = 0$, we have integral equation for determination of factor Q

$$\frac{2Nua\alpha_2}{\alpha_1 \pi t_0} \int_0^{\frac{\pi}{2a}} \frac{\sin^2 ka}{\sqrt{1 - \sin^2 ka [1 - (\frac{2uQ}{t_0})^2]}} dk = 1. \quad (8)$$

In the case $|\frac{2uQ}{t_0}| < 1$ and in the case $|\frac{2uQ}{t_0}| > 1$ Q was evaluated from the relation (8) approximately. In the case $\frac{2uQ}{t_0} = 1$ parameter Q was calculated exactly. The quasiparticles of the second kind at $Q = 1$ are quite similar quasiparticles in its mathematical description, that those ones, which were obtained in [13], [14]. It was found, that SSH-like solution is unapplicable for the description of standard processes, passing near equilibrium state by any parameters. The quasiparticles, described by SSH-like solution, can be created the only in strongly nonequilibrium state with inverse population of the levels in c - and v -bands. At the same time, the first solution can be realized both in near equilibrium and in strongly nonequilibrium states of the " π -subsystem" of boson-"atomic" chain, which is considered to be quantum Fermi liquid. The continuum limit for the ground state energy of boson-"atomic" chain with SSH-like quasiparticles will coincide in its mathematical form with known solution [14], if to replace $\Delta_k Q \rightarrow \Delta_k$. Let us calculate the ground state energy $E_0^{[u]}(u)$ of the boson-"atomic" chain with quasiparticles' branch, which is stable near equilibrium. Taking into account, that in ground state $n_{k,s}^c = 0$, $n_{k,s}^v = 1$, in the continuum limit we have

$$E_0^{[u]}(u) = -\frac{2Na}{\pi} \int_0^{\frac{\pi}{2a}} \frac{(Q\Delta_k)^2 - \epsilon_k^2}{\sqrt{(Q\Delta_k)^2 + \epsilon_k^2}} dk + 2NKu^2, \quad (9)$$

then, calculating the integral, using the complete elliptic integral of the first kind $F(\frac{\pi}{2}, 1 - z^2)$ and the complete elliptic integral of the second kind $E(\frac{\pi}{2}, 1 - z^2)$, we obtain

$$E_0^{[u]}(u) = \frac{4Nt_0}{\pi} \{F(\frac{\pi}{2}, 1 - z^2) + \frac{1 + z^2}{1 - z^2} [E(\frac{\pi}{2}, 1 - z^2) - F(\frac{\pi}{2}, 1 - z^2)]\} + 2NKu^2, \quad (10)$$

where $z^2 = \frac{2Q\alpha_1 u}{t_0}$. Approximation of (10) at $z \ll 1$ gives

$$E_0^{[u]}(u) = N \left\{ \frac{4t_0}{\pi} - \frac{6}{\pi} \ln \frac{2t_0}{Q\alpha_1 u} \frac{4(Q\alpha_1)^2 u^2}{t_0} + \frac{28(Q\alpha_1)^2 u^2}{\pi t_0} + \dots \right\} + 2NKu^2. \quad (11)$$

It is seen from (11), that the energy of quasiparticles, described by the first solution, has the form of Coleman-Weinberg potential with two minima at the values of dimerization coordinate u_0 and $-u_0$ like to the energy of quasiparticles, described by SSH-solution for t-PA [14].

Therefore, all qualitative conclusions of the model proposed in [14] are holding in Fermi-liquid consideration of " π -subsystem" of the chain (instead of Fermi-gas consideration) for the quasiparticles, corresponding to the second-branch-solution. It is evident, that the mechanism of the phenomenon of spin-charge separation in Fermi-liquid is soliton mechanism, analogous to the mechanism proposed by Jackiw and Rebbi [11] on the basis of field theory positions and to the mechanism proposed by Luther and Emery [10], but it is quite different from Anderson spinon-holon mechanism [12].

Thus, the results obtained allow to propose the reasonable explanation of the existence in the fields with charges of chargeless particles - solitons with nonzero spin value, which in the case of EM-field is equal to $\frac{1}{2}$ instead prevalent viewpoint, that photons possess by spin $S = 1$. The photons in quantized EM-field are main excitations in oscillator structure, which is equivalent to spin $S = 1$ boson-"atomic" structure, like mathematically to well known spin $S = 1$ boson matter structure - carbon atomic backbone structure in many conjugated polymer chains. The

photons have two kind nature. The photons of the first kind represent themselves neutral EM-solitons of SSH-soliton family. They are main excitations in so-called "undoped" structure of EM-field, including free EM-field in vacuum. Naturally, they have nonzero size, that is they cannot be considered to be point objects. It seems to be evident, that like to Fermi-gas SSH-model, the main excitations in "doped" boson-"atomic" structure of EM-field will be charged spinless EM-solitons, which also can be referred to SSH-soliton family. It is reasonable to suggest, that "doping" can be effective in the medium like to rain-clouds, although detailed mechanism has to be additionally studied. The representation of photons to be the result of spin-charge separation effect and their assignment with main excitations in ground state of " π -subsystem" in rest massless boson-"atomic" EM-field structure - chargeless spin $\frac{1}{2}$ topological solitons - makes substantially more clear the nature of corpuscular-wave dualism. Really, like to matter atomic structure, the quantized EM-field represents itself the discrete boson-"atomic" structure, the separate bosons in which produce the structure like to atomic structure in condensed matter. The main difference between EM-field "atomic" structure and atomic structure in condensed matter consists in that the "atoms" in EM-field structure have zeroth rest mass. The origin of wave in given structure is determined by the mechanism, quite analogous to Bloch wave formation in solid state of condensed matter. It is harmonic trigonometric functions for Maxwellian EM-field, which determine wave character of quantized Maxwellian EM-field. At the same time there are simultaneously the corpuscles, propagating along given EM-field boson-"atomic" chain structure, that is, chargeless spin $\frac{1}{2}$ topological relativistic solitons - photons, formed in usual conditions (or spinless charged solitons in so-called "doped" EM-field structure). It becomes now to be understandable, that the display of the corpuscular or wave nature of EM-field will be dependent on experimental conditions.

Let us remark, that the model proposed is in fact the development of an idea of multiphoton "molecules". The idea of multiphoton "molecules" arose at the earliest stage of quantum physics around 1910, and it belongs to Debye [16]. Debye presented in above cited work a simple, ondulatory method to obtain the radiation law. Let us remark, that the derivation of the complete radiation formula from the corpuscular concept of the photon "molecules" has been obtained the only relatively recently, on the frontier of the millennia, in 2000, in [18]. The authors of [18] have obtained the complete radiation formula on the base of Debye photon "molecules" idea, using the description of 'multiphoton states' in multiphoton "molecules", which was proposed in [17]: light of definite direction and frequency ν presents itself in units "molecules" of 0, 1, 2, ..., n, ...photons, with energy $nh\nu$, that is, with zero binding energy, and they contribute independently to the energy density. The authors of [18] accentuate, that given assumption is rational, it is in the spirit of the atomistic Democritean viewpoint, and it means that all the photons of the same frequency are identical.

Especially interesting, that we came quite independently to boson chain description of EM-field, the photons in which, being to be noninteracting between themselves topological solitons in the atomistic 1D-chain structure of the linearly polarized light, can really be represented by 1D "molecules" of 0, 1, 2, ..., n, ...quasiparticles, with energy $nh\nu$, that is, with zero binding energy, in full accordance with the model, proposed by [16], [17], [18]. On the existance of the works [16], [17], [18] we have got to know quite recently. However given independence seems to be testifying on the correctness of Debye idea and its development in subsequent works, including our work.

Let us give the experimental confirmations of the model proposed.

Very strong argument in favour of the model proposed is the well known experimentally observed phenomenon of electron-positron annihilation. It is well theoretically described, see, for example [19], and experimentally confirmed that by direct annihilation of electron-positron pair two photons are produced. At the same time the explanation for the case of the relative velocity of annihilating particles near to zero, how can be produced from two particles with spin

value $1/2$ also two particles, however with spin value 1, is in fact absent. It is evident, that the boson model presented explains given disagreement between experimental data on electron-positron annihilation and the theoretical viewpoint on the photon to be the spin-1 particle in a natural way - from two particles with spin values $1/2$, that is from electron-positron pair can be produced two photons the only with spin values $1/2$.

The second argument is the existence of the dependence of a resonance microwave absorption rate on the spin value of absorbing centers, which was found in electron spin resonance (ESR) spectroscopy for the first time in [20], [21]. It was established, that spin 1-centers absorb microwave power with the rate exceeding the the absorption rate by spin $1/2$ -centers precisely two times more. From give result it follows the reasonable suggestion, that if the photons were possessing by spin 1 they couldn't be absorbed in ESR conditions by the centers with the spin value $1/2$ (like to the absence of any ESR-absorption by the centers with zeroth spin value).

The third argument is the following. In the concept of elementary paticles existing at present "the Higgs boson emerges and disappears by borrowing energy from and returning energy to the particles in the electroweak interaction, respectively. The returning of energy from the Higgs scalar boson to the particles is through the absorption of the Higgs scalar boson by the particles. When a massless particle in the electroweak interaction absorbs the Higgs scalar boson, the Higgs scalar boson becomes the longitudinal component of the massless particle, resulting in the massive particle and the disappearance of the Higgs scalar boson" [22]. According to [22] "The observed Higgs boson at the LHC is a remnant of the Higgs boson. At the beginning of the universe, all particles in the electroweak interaction were massless. The Higgs boson appeared by borrowing energy symmetrically from all particles in the electroweak interaction. The Higgs boson coupled with all massless particles, including leptons, quarks, and gauge bosons, in the electroweak interaction. All massless particles except photon absorbed the Higgs boson to become massive particles. The asymmetrical returning of energy from the Higgs boson by the absorption of the Higgs boson is called the symmetrical breaking of the electroweak interaction in the Standard Model. In the cases of such massive particles, including leptons, quarks, and weak gauge bosons, the Higgs boson disappeared. In the case of massless photon the un-absorbed Higgs boson became the remnant of the Higgs boson. Being specific to the electroweak interaction, the remnant of the Higgs boson could not return the borrowed energy to any other massless particles". So it is established that the photons occupy a peculiar place regarding the interaction with Higgs bosons. From here follows also the reasonable suggestion, that the photons cannot be considered to be the gauge bosons of electromagnetism, possessing by spin 1.

3. Conclusions

New model of photons is proposed. The photons in quantized EM-field are main excitations in oscillator structure of EM-field, which is equivalent to spin $S = 1$ rest massless boson-"atomic" structure, like mathematically to well known spin $S = 1$ boson matter structure - carbon atomic backbone chain structure in many conjugated polymers. They have two kind nature. The photons of the first kind represent themselves neutral chargeless topological EM-solitons of SSH-soliton family. The photons of the second kind represent themselves charged spinless EM-solitons, which also can be referred to SSH-soliton family. The origin of waves in given structure is determined by the mechanism, quite analogous to Bloch wave formation in solid state of condensed matter. At the same time, the existence simultaneously of the corpuscules, propagating along given EM-field boson-"atomic" chain structure, that is, chargeless spin $\frac{1}{2}$ topological relativistic solitons - photons, formed in usual conditions (or spinless charged solitons in so-called "doped" EM-field structure) clarifies the nature of corpuscular-wave dualism.

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