The string theory of Compton wavelength scale as generalization of Standard Model theory
(Non-linear quantized electromagnetic wave theory)

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Synopsis

Introduction. Solitons - a solitary stable wave

A solitary wave is defined as a spatially confined, non-dispersive and non-singular solution of a non-linear field theory.

For particle physicists a stable wave is a good model for elementary particles opening up in a non-linear field theory the possibility of what would have to be a wave packet in a linear one (newer fundamental gauge theories are non-Abelian and therefore non-linear).

For any non-linear theory the soliton is a fundamental solution as every other. Doing quantum mechanics one finds relations between solitons and elementary particles that go very deep and are entirely unexpected from a classical viewpoint.

Below the synopsis of the non-linear theory of the quantized electromagnetic waves with new type of non-linearity is offered, whose objects are identical with the objects of quantum field theory (QFT) and of the modern theory of strings.

The theory for brevity is referred to as curvilinear waves electrodynamics – CWED.

1.0. Axiomatics of CWED

The axiomatic basis of the offered theory is made of 6 postulates, the first 4 of which are postulates of the modern field theory. Postulates 5 and 6 express the specificity of CWED; they do not follow directly from modern physics, but also do not contradict to it.

1. A postulate of fundamentality of an electromagnetic field: the self-consistent Maxwell-Lorentz microscopic equations are the independent fundamental field equations.

(We shall remind, that generally the fields and currents of these equations are interdependent, and the equations are thereof non-linear).

2. Postulate of quantization of electromagnetic waves: electromagnetic waves are the superposition of an elementary wave named photons, which have the certain energy and momentum, but zero rest mass.

3. A postulate of photon dualism: photons exist as real independent objects, which
   a) have the wave properties described by Maxwell-Lorentz equations and by the wave equation, following from them:
   b) and also have quantum properties, i.e. photons have certain, not deduced from Maxwell-Lorentz theory, but also not contradicting to it, the numerical characteristics, determined by a below-mentioned postulate of Planck.

4. Planck's postulate: Connection between energy and frequency of a photon is set by the Planck formula.

5. Postulate of photon nonlocality.

   Since this postulate is central in our theory, it demands a serious substantiation of its consistency to modern results.

In framework of QED (Ahiezer and Berestetski, 1969), as the field equations, describing a quantum-mechanical state of a photon, the second order wave equations for EM field vectors \( \mathbf{E} \) and \( \mathbf{H} \), following from the Maxwell-Lorentz equations, are used.

In this case the photon wave function is entered by the following method. Factorizing the wave equation to the equations for retarded and advanced waves, we receive two equations of the first degree concerning function \( f_k \), which is some generalization of the EM field vectors and adequates to a wave vector \( k \). The equation for this function is equivalent to the Maxwell-Lorentz equations. It has appeared, that function \( f_k \) can be interpreted as wave function of a photon in momentum space. But it does not
allow to describe an interaction of a photon in the local point of space. For this aim the wave function in the coordinate representation is required.

But in an attempt to enter the photon function in the coordinate representation, was found out an insuperable difficulty. According to analysis of Landau, L.D. and Peierls, R. (Landau and Peierls, 1930) and later Cook, R.J. (Cook, 1982a; 1982b) and Inagaki, T. (Inagaki, 1994) the photon wave function is nonlocal.

Actually, having made the inverse Fourier transformation of above \( f_k \) function:

\[
\frac{1}{(2\pi)} \int f_k e^{i\mathbf{k} \cdot \mathbf{r}} d^3k = f(\mathbf{r},t),
\]

it is apparently possible to define \( f(\mathbf{r},t) \) as the photon wave function in coordinate representation. But the \( f(\mathbf{r},t) \) function is not defined by the value of the field \( \tilde{E}(\mathbf{r},t) \) in the same point; it depends on the field distribution in some area, which sizes are of the order of the photon wavelength. This means, that the localization of a photon in a smaller area is impossible and, hence, the value \( |f(\mathbf{r},t)|^2 \) will not have the sense of probability density to find a photon in the given point of space.

The linear object, which, on the one hand, obeys the wave equation, and on the other hand has some size, is referred to as a \textit{string}. Thus, within the framework of CWED it is admissible to describe a photon as an elementary electromagnetic wave - an electromagnetic string (not forgetting of course that this supposition cannot have any relationship to the real structure of a photon). This allows us to formulate the following postulate ("\textit{the postulate of a photon string}"):  

\textbf{Postulate 5.} Within the framework of CWED the fundamental particle of an EM field - the photon - can be described as a relativistic string of one wavelength size, which corresponds to its energy according to Planck's formula.

The main proof of validity of this postulate is the opportunity to construct on its basis the theory, which coincides completely with the existing quantum field theory (QFT).

\section{A postulate of formation of massive electromagnetic particles: Within the framework of CWED under the certain external conditions the EM-string can start to move along the closed curvilinear trajectory, forming the objects, named by us the electromagnetic particles.}

As is known, the bending of a trajectory of an EM wave in the strong EM field follows already from the Maxwell-Lorentz theory. Thus, strictly speaking, the opportunity of an EM wave propagation along a curvilinear trajectory does not demand a special postulate.

At the same time, it is obvious, that due to the quantum nature of a photon (EM-string) the formed particles should possess, at least, a rest mass and the angular momentum (spin). Moreover, the detail analysis shows that such elementary particles can have electric charge, helicity and all other characteristics and parameters of real elementary particles.

\section{The non-linear quantum field theory without formulas}

According to the postulate 5, the photon as part of EM wave (i.e. as EM-string) can have the following graphic representation (which, note again, doesn’t have any connection with the unknown to us real photon structure) (see fig. 1).

![Fig.1](image-url)
We know nothing about what happened in the “birthplace” of a pair. We only see the beginning and the end of the process. **What transformation could take place with massless photon in a field of an atom nucleus, which has led to the occurrence of two, conditionally motionless particles, both with mass and spin, equal to half of energy and spin of a photon, and also with mutually opposite electric charges?**

According to a postulate 6 for particle formation a photon should to be twirled into a ring, and according to fig. 2 it should then be divided in two halves, i.e. into other two rings, which can move now with a speed other than the speed of light. Obviously, a twirled photon gets the mass that is equal to energy of a photon, divided on a square of light speed and as it is easy to show, has a spin, equal to one.

Apparently, after the photon dividing we receive two particles with rest mass equal to half of mass of a twirled photon and with spin equal to half the spin of a photon.

Let’s try to find the theoretic description of this process. Return again to a fig. 2 of the electron-positron pair production process. Conditionally speaking, we see, how from the left the Maxwell equation of electromagnetic wave ”flies into“ a very strong electromagnetic field of a nucleus. On the right we see then two Dirac equations (one for electron, another for positron) “fly out” (fig. 3).

Thus, according to our scheme it follows that the Dirac equations are the field equations each of two parts of the twirled EM wave.

Does this assumption contradict to the existing field theory?

Actually, as it is known, the Dirac equations have others transformation properties, than Maxwell-Lorentz equations: the wave function of Maxwell-Lorentz equations is vector, whereas the function of Dirac equation is named spinor (from “to spin”). But remember in this connection, that the Dirac equation in the fiftieth years is named the “semi-vector” equation, and their wave function – “semi-vector” because the last are connected with the vector field by certain relations (see, for example, (Goenner, 2004)).

In addition, as is known, the Maxwell-Lorentz time depending equations contain six vectors and six equations (the source equations are possible to consider as the initial conditions). At the same time the spinor Dirac electron equation contains two wave functions and two equations, and the bispinor - accordingly, four. It is easy to see, that here does not exist any contradiction. In EM-string theory there is a question about the electromagnetic waves, not about EM field generally. The last do not contain the longitudinal field components and this property is Lorentz-invariant. In our case one plane polarized EM wave contains two field vectors and generates one spinor. At the same time, one circle polarized EM wave contains four field vectors and generates two spinors, i.e. bispinor.

Obviously to adjust these requirements, it is necessary the division of the twirled photon to be a special process. But how can the twirled photon be divided so that two antisymmetrical particles with spin half appear? Unique opportunity of such process is the division of the twirled photon into two twirled half-periods of photon according to following scheme (fig. 4):
Thus, conditionally speaking, from one vector particle we receive two semi-vector particles, (two spinors) which according to figure 4 are fully antisymmetrical.

In the present theory it is shown consistently from mathematic point of view, how an electromagnetic equation of the twirled wave (not the classical Maxwell-Lorentz equations, but some nonlinear equation of EM field !) is derived from the EM wave equation. Then from the last the equations of the twirled half-period waves are deduced, which in the matrix form are the Dirac equations.

Further it is also shown, that all quantum-mechanical values and characteristics (including statistical interpretation of wave function, bilinear forms, etc., etc.) in electrodynamics of curvilinear EM waves have simple physical sense. Thus, CWED includes quantum mechanics as the formal linear mathematical structure, and, certainly, does not cancel any of its results, but only explains them and yields additional results.

In the research it is shown that the current (charge) of electron (positron) is an additional part of the Maxwell displacement current, which appears due to the transport of electrical wave vector along the curvilinear trajectory (fig. 5):

Here three vectors – electrical, magnetical and Poynting vector – comprise the trihedron, corresponding to trihedron of unit vectors – normal, binormal and tangential – which are known in the differential geometry as Frene-Serret trihedron.

It also appears, that this additional term corresponds to connection coefficients of Ricci (in case of leptons) or of Cristoffel (in case of hadrons), which characterize the turns of field vectors at their motion in curvilinear space.

Since electron and positron correspond to two twirled half-period waves of one photon, it follows from this fact that in Universe the numbers of positive and negative charges must be always fifty-fifty (this leads to the charge conservation law and the neutrality of Universe).

In the framework of CWED the interaction among particles in the electron equation appears automatically in the moment of break of the neutral twirled photon into two charged particles. It corresponds to the expression of the minimal interaction, which in existing quantum electrodynamics is entered by "hand" or by means of gauge transformation (the last one, as is known, represents, according to formal terminology of QFT, the description of rotations "in internal space of symmetry" of particles).

Are there still the bases to accept this approach? Yes, there are, and very serious ones.
1. In this case the optics-mechanical analogy of Hamilton, from which all quantum theory began, finds its substantiation (actually CWED is the optics of curvilinear waves, which simultaneously can describe the motion of the matter objects).

2. The occurrence of Pauli's matrixes, which describe the rotation in classical mechanics in 2D space in the Dirac electron and positron equations, receives an explanation as well as the occurrence of Gell-Mann matrixes in the Yang-Mills equations, which describe the rotation in 3D space.

3. The necessity of a nucleus electromagnetic field receives an explanation: it serves the medium with the big refraction number, leaning on which the light string bents (obviously this requirement is identical to the requirement of conservation of system momentum).

4. The formed EM particles are simultaneously both waves and particles (i.e. the wave - particle dualism is inherent to them).

5. Since the twirled photon has integer spin (it is a boson), but the twirled semi-photons have spin half (it is a fermion), we automatically receive an explanation of division of all elementary particles into bosons and fermions.

6. It is easy to see, that the fig. 4 reflects the process of spontaneous symmetry breakdown of an initial photon and occurrence of mass of elementary particles, which have place in presence of a nucleus field, as some catalyst of the reaction (playing here the role of Higgs boson).

7. If in the theory of static spherical electron of Lorentz classical theory there are no the electromagnetic forces, capable to constraint the repulsion of electron parts from each other and it is necessary to enter Poincare's forces of non electromagnetic origin, then it is easy to see, that here, owing to presence of a current, there is the magnetic part of full Lorentz force directed against electrostatic forces of repulsion and counterbalancing them. Thus, such electron does not demand the introduction of extraneous forces of an unknown origin and is stable.

About some other consequences, which follow from the suggestion about photon twirling, we will briefly talk below.

In the research it is also shown that at plane twirling and division of the circularly polarized initial photon are produced the neutral massive leptons – the same type as neutrino and antineutrino, which are also described by Dirac equations. Figure 6 shows the distribution of the electric field connected with the circularly polarized wave of the positive (right) and negative (left) helicity:

Fig. 6

The twirled half-periods of such photons give the EM particles with inner helicity (fig.7).

Fig. 7

In this case neutrino as twirled helicoids represents Moebius's strip: its field vector at end of one coil has the opposite direction in relation to the initial vector, and only at two coils, comes back to the starting position (fig. 8). This property of the EM-lepton vector corresponds to the same property of wave function of Dirac lepton theory.
The mass of a particle is defined by integral from density of energy, which is proportional to the second degree of field strength. In this case the integral is always distinct from zero if the field strength is distinct from zero.

At the same time the particle charge is defined by integral from density of a current, which is proportional to the first degree of field strength. Obviously, there is a chance, when the sub-integral expression is not equal to zero, but the integral is equal to zero. It is easy to check, that we will receive such result in case of EM neutrino, since the sub-integral function changes under the harmonious law.

It is interesting that according to R. Feynman (Feynman, 1987) the particle, which has the Moebius strip topology, must obey the Pauli exclusion principle. Thus in the framework of CWED the EM elementary particles must be behave as fermions of quantum field theory.

Further in research it is described the occurrence of spatial particles, as the superposition of the twirled half-photons. The equations of such particles coincide with Young-Mills equations for hadrons (mesons and baryons). In this case the spatial superposition of two twirled semi-photons generates the mesons, and spatial superposition of three twirled semi-photons leads to occurrence of baryons, e.g. proton (fig. 9):

In this case a Frene-Serret trihedron moves in three-dimensional space, continuously turning. Therefore the current of each loop will no more be constant as it took place for a circular trajectory, and will change its size. Hence, the charge of each loop will be less than the charge of electron.

If to identify the separate elements of superposition (i.e. the spatial twirled semi-photons) with quarks, we can receive an explanation of the experimental facts, inexplicable in frame of SM. First, there is a clear relationship between quarks and leptons. Secondly, becomes understandable the confinement of quarks and gluons. Thirdly, the distinction of elementary particles into three groups - leptons, mesons and baryons - receives an explanation. Fourthly, the fractionality of charges of quarks receives an explanation too, as many others.

In the research it is also shown the possibility of other particle formation as well as the particle parameters calculation.

3. About electron particle size and “hidden variables” in quantum theory

Within the framework of CWED electron is the electromagnetic field of a special configuration, concentrated in small volume with characteristic size of Compton wavelength.

Does the presence of the electron “size” in framework of CWED contradict to its absence in the Dirac
theory? No, since in both cases this is the same equation - the Dirac electron equation.

But how the same equation can contain and simultaneously not contain a “size”? Here we approach to very interesting result of CWED, which solves numerous disputes and the doubts, continuing many years: are there in the quantum mechanics "hidden parameters"; is it possible to enter them, not destroying the quantum mechanics, etc. Here it appears that von Neumann was partially right, who has proved that it is impossible the hidden parameters to enter into the given scheme of QM, but also de Broglie, D. Bohm and others are right, which have shown, that the Neumann's proof is limited by framework of existing interpretation.

It appears that **nothing more must be entered into the existing equations because everything, what is necessary, here already exists.** In the Dirac electron equation already there is a size of electron, but it is “hidden” not by the features of the quantum theory, but by the form, in which we represent and interpret it. Let’s explain this statement.

The current term of the CWED electron equation is connected with parallel transport of a field vector along a curvilinear trajectory. It is defined by the curvature of a trajectory (or, in other representation, the Ricci coefficient of rotations), which are expressed by Compton electron wavelength: \( r_c = \hbar/m_e c \) (where \( m_e \) is the “bare” electron mass and \( c \) is the light speed). So, for the curvature of a trajectory we have term \( 1/r_c = m_e c/\hbar \), which is in the same time the free term of Dirac electron equation.

Thus, until we do not know that the Dirac equation the electron radius contains, it really is the "hidden" parameter. But, on the other hand, it is "hidden" only because the accepted and canonized form of QM. So, the existing of radius does not contradict to the quantum mechanics in any way.

Simultaneously we can understand occurrence of other "hidden" parameters of electron - for example, the parameters of so-called "Zitterbewegung" - "trembling" or, more correctly, oscillatory motion of relativistic electron, found out by Schroedinger. From Dirac equation follows absolutely correct, that the motionless electron has the oscillatory motion, having: 1. The amplitude equal to half of length of Compton wave; 2. The frequency equal to speed of light, devided on half of length of Compton wave; and 3. Electron always has speed of light. It is easy to understand, that if to identify the "Zitterbewegung" with rotation of a semi-photon fields (see fig. 4) these "hidden" parameters cease to be "hidden".

**Bibliography**


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