Crisis in quantum field theory and its overcoming. (axiomatic approach versus heuristic)

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Many known scientists have noted the presence of crisis in fundamental physics. Despite mathematical success, quantum theory not answers many questions that are asked by scientists. Which of our basic physical assumptions are wrong? What we need to change? The proposed article tries to answer these questions using a new approach.

1.0. Crisis in Physics

A considerable number of prominent scientists says about the crisis in fundamental physics, which is reflected in the fact that the last 40 years in this field of science there are no new results (Smolin, 2006; Woit, 2007; Seth, 2007; Schroer, 2008; Schroer, 2009; Horgan, 1996; etc)..

So, well-known physicist Lee Smolin in his book (Smolin, 2006) notes:

"*The story I will tell could be read by some as a tragedy. To put it bluntly – and to give away the punch line – we have failed. We inherited a science, physics that had been progressing so fast for so ling that it was often taken as the model for how other kinds of science should be done. For more than two centuries, until the present period, our understanding of the laws of nature expanded rapidly. But today, despite our best effort, what we know for certain about these laws is no more than what we knew back in the* 1970*s.*

How unusual is it for three decades to pass without major progress in fundamental physics? Even if we look back more than two hundred years, to a time when science was the concern mostly of wealthy amateurs, it is unprecedented. Since at least the late eighteenth century, significant progress has been made on crucial questions every quarter century"…

Why is physics suddenly in trouble? And what can we do about it? These are the central questions of my book…".

The presence of the crisis is also confirmed by the philosophers:

(Popper, 1982) "*Today, physics is in a crisis. Physical theory is unbelievably successful; it constantly produces new problems, and it solves the old ones as well as the new ones. And part of the present crisis—the almost permanent revolution of its fundamental theories—is, in my opinion, a normal state of any mature science. But there is also another aspect of the present crisis: it is also a crisis of understanding.*

This crisis of our understanding is roughly as old as die Copenhagen interpretation of quantum mechanics. It is thus a little older than die original edition of The Lope of Scientific Discovery. In this part of die Postscript I have tried to make again a number of proposals intended to clarify what underlies this crisis of understanding".

The question arises about the causes of the crisis of fundamental science.

2.0. Which of our basic assumptions are wrong?

Although they use different terminology, physicists and philosophers converge to the same reason. Here is what Popper says (Popper, 1982):

"*In my view, the crisis is, essentially, due to two things:*

(a) *the intrusion of subjectivism into physics; and*

(b) *the victory of the idea that quantum theory has reached complete and final truth.*

Subjectivism in physics can be traced to several great mistakes. One is the positivism or idealism of Mach. It spread to the British Isles (where it had been originated by Berkeley) through

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Russell, and to Germany through the young Einstein (1905). *This view was rejected by Einstein in his forties* (1926), *and it was deeply regretted by the mature Einstein* (1950). *Another is the subjectivist interpre¬tation of the calculus of probability, which is far older and which became a central dogma of the theory of probability through the work of Laplace*".

Let us consider what the reasons are consistent with this in science.

Simplistically, we can say that science is a method of obtaining the answer to a question in order to gain some benefit for people.

Since Nature is only one, only one answer to each question must exist as well as one picture of each phenomenon. Such an answer is usually called true or correct. Methods that are used in order to obtain only one answers from Nature are named the methodology of science. In practice, methodology of science is a number of regulations.

The basis of methodology of scientific theory is nowadays a law (which conditionally can be named "**Francis Bacon** law of **science methodology**" (SEPh, 2003):

«Scientific community has taken that any theory is true, if it is in agreement with experimental results when these experiments are invariant with respect to the space, time, experimentalists, technical means and some other conditions».

In other words, to announce a verdict about the truth of the theory, the experiments should give identical results in Moscow, Los Angeles, on the Moon or Aldebaran; a hundred years ago, today, tomorrow, after a thousand years; by experimentalists from USA, Argentines, Mars or Venus; by means of any device, which is fit for a given experiment; and the results of the experiment must be mathematically processed and presented by known methods.

Assuming all of this, the Bacon law can be summarized as follows: "*The coincidence of theoretical results with experimental results is the truth in science*".

This law is regularly worked until the early 20th century. But, as the science development shows, there is some incompleteness in the Bacon law: this law says nothing about the method of construction of theory and about theory structure. As it turned out, the absence of this indication also leads to a crisis in science. In particular, we assume that one of the main causes of the current crisis is precisely this point. What grounds are there for such a statement?

Historically, there are two aspects of mathematics. Proof-based mathematics is not the only form (Davis and Hersh, 1982).

"*The mathematics of Egypt, of Babylon, and of the ancient Orient was all of the algorithmic type. Dialectical mathematics -- strictly logical, deductive mathematics -- originated with the Greeks. But it did not displace the algorithmic.In Euclid, the role of dialectic is to justify a construction-i.e., an algorithm. It is only in modern times that we find mathematics with little or no algorithmic content. [. . .] Recent years seem to show a shift back to a constructive or algorithmic view point.*"

It turned out that this difference is also characteristic for physics of XX-XXI centuries. Richard Feynman caught the attention of physicists on this particularity . In a series of lectures "The Character of Physical Law " (Feynman, 1964), he analyzed these issues in detail. The following are typical excerpts from his book:

"*...there are two kinds of ways of looking at mathematics, which for the purpose of this lecture I will call the Babylonian tradition and the Euclidean or Greek tradition. In Babylonian schools in mathematics the student would learn by doing a large number of examples until establishing the general rule... Tables of numerical quantities were available so that they could solve elaborate equations.*

Under the Babylonian system, everything was prepared for calculating things out. But Euclid (under the Greek mathematical system) discovered that there was a way in which all of the theorems of geometry could be ordered from a set of axioms that were simple. The Babylonian *mathematics is that you know all of the various theorems and many of the connections in between...*".

The next step is then the guessing of physical equations, which, Feynman argues, facilitates the guessing of new physical laws in a way that common-sense feeling, philosophical principles, or models cannot.

Feynman (Feynman, 1964) argued that, "*In physics, we need the Babylonian method, and not the Euclidian or Greek method*."

The Babylonian tradition and the Euclidean or Greek tradition in the framework of physics and mathematics can be named “algorithmic approach” and “axiomatic approach”; following Karl Popper (Popper, 1982), they can be called "instrumentalism" and "realism"; recalling the T. Kuhn analysis (Kuhn, 1962), we can also name these methods “Babylonian paradigm” and “Greek paradigm”; or “neo-positivistic approach” and “classical approach” (Mach, 1897; Holton, 1968)).

In framework of “Babylonian approach” (see, for example, the mathematical cuneiform tablets of Mesopotamia, Egypt papyri, the Ptolemeus astronomy theory) the theory is formulated in the form of regulations, rules, recipes of calculations found in any way, including through trial and error or the method of fitting. It is clear that the number of these regulations, rules and prescriptions should be almost as great as the number of questions to be answered. Any mathematic apparatus can be invented here to obtain the result, without understanding its connection with other part of theory.

In contrast, according to “Greek approach” for each area of science must exist one of the equivalent systems of axioms, and all mathematic results of the theory must follow consecutively from this axiom system (for examples see the Euclid geometry and classical mechanics of Newton).

Although both approaches are not against the Bacon law, it is difficult to disagree with the fact that a scientific theory, which enjoys a huge number of practical recipes and instructions, found by means of trial and error method, contradicts to our intuitive understanding of the unity of the world picture (Planck, 1910).

"Is the physical picture of the world, only more or less an arbitrary creation of our mind, or, conversely, we have to admit that it reflects a real, totally independent from us, phenomena of nature? ...

If, on the basis of the above, I answer affirmatively this question, I am well aware that the answer lies in a certain contradiction with the direction of the philosophy of nature, which is headed by Ernst Mach and which now enjoys great sympathy among scientists. According to this doctrine, in nature there is no other reality other than our own feelings, and every study of nature is, ultimately, only the economical adaptation of our thoughts to our feelings, to which we come under the influence of the struggle for existence. The difference between the physical and mental is purely practical and conventional; i.e. the unique elements of world - this is our experience.

Although I am firmly convinced that in the Mach system, if it is consistently held, there is no self-contradiction, it seems to me no less significant that its value is, in essence, purely formal and does not concern the foundations of science. The reason for this is that the Mach system is completely alien to the most important attribute of any natural science research: the desire to find a permanent, independent of change of times and the people, world picture ...

The goal does not lie in the complete adaptation of our ideas towards our sensations, but in the complete liberation of the physical picture of the world from the individuality of the creative mind. This is a more precise statement of what I described above as the exemption from anthropomorphic elements.

When the great creators of the exact science - Copernicus ..., Kepler ..., Newton ..., Huygens…, Faraday, ... - introdused their ideas to science, surely none of these scientists have relied on the economic point of view in the fight against the inherited beliefs and overwhelming authority. The *support of all their activities was the unshakable belief in the reality of their world view. In view of this undoubted fact, it is difficult to get rid of the fear that the train of thoughts of leading minds would be violated, the flight of imagination weakened, and the development of science would be fatally delayed, if the principle of economy of Mach really became the focal point of the theory of knowledge. Maybe it will actually be more "economical" if we give the principle of economy a more modest place*?"

After 40 years, in 1952, E. Schrodinger even more clearly expressed dissatisfaction with algorithmic (Babylonian, neopositivistic) development of modern physics (Schrödinger, 1952):

(Quotes from Part I) "*The innovations of thought in the last o years, great and momentous and unavoidable as they were, are usually overrated compared with those of the preceding century; and the disproportionate foreshortening by time-perspective, of previous achievements on which all our enlightenment in modem times depends, reaches a disconcerting degree according as earlier and earlier centuries are considered… A theoretical science, where this is forgotten, and where the initiated continue musing to each other in terms that are, at best, understood by a small group of close fellow travellers, will necessarily be cut off from the rest of cultural mankind; in the long run it is bound to atrophy and ossify, however virulently esoteric chat may continue within its joyfully isolated groups of experts...*

The disregard for historical connectedness, nay the pride of embarking on new ways of thought, of production and of action, the keen endeavour of shaking off, as it were, the indebtedness to our predecessors, are no doubt a general trend of our time…

There is, however, so I believe, no other nearly so blatant example of this happening as the theories of physical science in our time...

There have been ingenious constructs of the human mind that gave an exceedingly accurate description of observed facts and have yet lost all interest except to historians. I am thinking of the theory of epicycles".

(Quotes from Part II) "*There is, of course, among physicists a widely popular tenet, informed by the philosophy of Ernst Mach, to the effect that the only task of experimental science is to give definite prescriptions for successfully foretelling the results of any future observations from the known results of previous observations.*

If our task is only to predict precisely and correctly by any means whatsoever, why not by false mathematics?"

3.0. Algorithmic mathematics vs. axiomatic

3.1. Why is the modern theory of elementary particles called the Standard Model?

Modern theoretical physics does not pretend to explain how something really happens in nature. Theoretical physics only claims that it can offer mathematical models that describe phenomena well, on the basis of which it is possible to make predictions, and then to test them experimentally.

Therefore, nothing restricts the mathematics that is needed for theoreticians to build models. For example, it is acceptable to use complex numbers if it turns out that with the help of complex numbers, it is possible to describe something that was not possible to describe with the help of real numbers; or, if it turns out that in order to describe the electrical and magnetic interactions of bodies it is convenient to introduce the notion of an electromagnetic field that is somehow "spilled" in space, then it is acceptable to do so. If it turns out that it is more effective as far as explanations and predictions are concerned, to use curved space-time to describe gravity, this is also acceptable.

The transition from one mathematical model to another does not necessarily have to be smooth, but can be accomplished abruptly. For example, we have a set of experimental facts that can not be described by the previous theory (say, classical mechanics). In addition it is not possible at a principled level; i.e., in classical mechanics there is simply no place for such phenomena. In this case we have to invent another mathematical formalism, in which the main role will be played by other objects.

For example, quantum mechanics is the kind of formalism that does not transition smoothly from classical mechanics, but is based on another basis. If some strange variants appear in the course of the development of a theory, they should be used if this mathematical model with its unusualness better describes the reality than any other models.

The same is true for the transition from quantum mechanics to quantum field theory. There, too, the rules of the game change: other objects become key-objects, and the formalism of working with them becomes more difficult. Most importantly, this theory should successfully describe and predict phenomena that could not be described by quantum mechanics.

In other words, modern theoretical physics does not represent an aggregation of knowledge in which all results follow consistently from a limited set of statements. It is rather a collection of disparate recipes – mathematical description models, poorly connected with each other and accepted by agreement by the majority of the scientists of the world.

Hence the name of the modern theory of matter: **Standard Model.**

Further we will examine the structure of the contemporary theory of elementary particles - Standard Model - and will note its " Babylonian" difficulties.

4.0. Difficulties of quantum field theory

The quantum field theory (QFT), (in particular, in the form of the Standard Model (SM)), is the contemporary theory of elementary particles and their interactions. Its predictions agree with experiments. But it has very strange peculiarities.

The most peculiar features of quantum mechanics are quantum nonlocality, indeterminism, interference of probabilities, quantization, wave function collapse during measurement. They and some others are basic principles of quantum mechanics that are generally accepted and called "The Copenhagen interpretation" :

1.A system is completely described by a wave function,

2.The description of nature is essentially probabilistic. The probability of an event related to the square of the amplitude of the wave function.

3. The wave function represent the state of the system, which grows gradually with time but, upon measurement, collapses suddenly to its original size.

4. Heisenberg's uncertainty principle: it is not possible to know the value of all the properties of the system at the same time; those properties must be described by probabilities.

5. Wave-particle duality. An experiment can show both the particle-like and wave-like properties of matter; in some experiments both of these complementary viewpoints must be invoked to explain the results, according to the complementarity principle of Niels Bohr.

6. Since measuring devices are essentially classical devices, it can measure only classical properties.

These peculiarities can not be explained on basis of quantum theory. Copenhagen interpretation describes the nature of the Universe as being much different then the world we observe.

The question arises, what grounds exist for the adoption of these concepts? It turns out that there are no bases, apart from the general agreement of physicists. As Niels Bohr (Bohr, 1962) said:

"*After a short period of ideological disorder and the disagreements, caused by short term of restriction of "presentation", the consensus about replacement of concrete images with abstract mathematical symbols, for example as , has been reached. In particular, the concrete image of rotation in three-dimensional space has been replaced by mathematical characteristics of representation of group of rotation*".

Many physicists have subscribed to the instrumentalist (or, according to R. Feynman, Babylonian) interpretation of quantum mechanics, a position, which is often equated with denial all interpretation. It is summarized by the sentence "Shut up and calculate!".

"*While expounding as the undisputed leader of the Copenhagen school, his peculiar mixture of positivism, realism, and existentialism, Bohr unfortunately did not anticipate the long-range effects of his teachings on future generations of physicists who lacked the philosophical training or the sophistication required to distinguish between subtle philosophical nuances and their gross over-simplifications. Such physicists condensed Bohr's entire philosophy into simplified enunciations of the principles of complementarity, wave-particle duality and the purportedly "classical nature" of the "apparatus," and simply ignored the rest. Indeed, what Karl Popper calls the "third group of physicists," who emerged right after World War II and soon became the overwhelming majority, is described by him as follows*(Prugovecki, 1992):

"*It consists of those who have turned away from discussions [concerning the confrontation between positivism and realism in quantum physics] they regard them, rightly, as philosophical, and because they believe, wrongly, many younger physicists who have grown up in a period of over-specialization, and in the newly developing cult of narrowness, and the contempt for the non-specialist older generation: a tradition which may easily lead to the end of science and its replacement by technology*." (Popper, 1982, p. 100).

4.1. What does the algorithmity of modern theories lead to?

Briefly and meaningfully about this peculiarity of QFT spoke one of the creators of SM, the Nobel laureate Murray Gell-Mann. (Gell-Mann, 1981):

"*Quantum mechanics, that misterious, confusing discipline, which none of us really understands but which we know how to use. It works perfectly, as far as we can tell, in describing physical reality, but it is a 'counter-intuitive discipline', as social scientists would say. Quantum mechanics is not a theory, but rather a framework, within which we believe any correct theory must fit.*"

According to (Anthony, 1985): "*The quantum mechanics … says nothing about the nature of the particles, forming the Universe, and about forces, which operate between them. More likely, it is the set of rules, with help of which it is possible to find, what will take place according to the given dynamic theory under certain conditions*"

Steven Weinberg in his book "*Dreams of the Final Theory* (1993) Chap. 4."Quantum Mechanics and Its Discontents" writes:

"*A year or so ago, while Philip Candelas (of the physics department at Texas) and I were waiting for an elevator, our conversation turned to a young theorist who had been quite promising as a graduate student and who had then dropped out of sight. I asked Phil what had interfered with the ex-student's research. Phil shook his head sadly and said, "He tried to understand quantum mechanics."*

In his "*Lectures on Quantum Mechanics* (2nd ed., 2015), Ch. 3 : General Principles of Quantum Mechanics" he explained this remark in more detail:

"*My own conclusion is that today there is no interpretation of quantum mechanics that does not have serious flaws. This view is not universally shared. Indeed, many physicists are satisfied with their own interpretation of quantum mechanics. But different physicists are satisfied with different interpretations. In my view, we ought to take seriously the possibility of finding some more satisfactory other theory, to which quantum mechanics is only a good approximation"*

It is necessary to recognize that such structure of theory is completely acceptable for the technical applications. But at the same time, for this reason, SM does not answer many questions that are entitled to be asked by any inquisitive mind (in framework of the QFT the answers are either separate postulates, or claims that our ability to know the micro-world is limited due to some of its features).

Among these, for example, are: what is the origin of the mass; why fundamental particles - electron and quarks - don't have size (i.e., are point); why the wave function has not a physical sense.

We do not know the physical meaning of quantization; uncertainty principle of Heisenberg; a wave-particle dualism; non-commutativity of dynamic variables; the operator form of QM; statistical interpretation of wave function; phase and gauge invariance; four-dimensional world; Pauli exclusion principle;

The theory does not explain elementariness of the charge; the charge and fine structure constant values; the "charges" of weak and strong interactions; universality of electron charge; existing of plus and minus charge of the particles; particle spin; helicity; the existing of different kinds of particles: intermediate bosons, leptons, mesons, baryons; and why other particles don't exist; confinement of the quarks; the stability and instability of the elementary particles; existence of particles and antiparticles; spontaneous breaking of symmetry; zittertbewegung; etc.

We do not know the physical sense of the mathematical characteristics of Dirac's electron equation: why the spinor equation does contain two equations, and the bispinor - four equations? Why into the Dirac equations the matrices are used, which in the classical theory describe the rotation? Why do the Pauli and Dirac matrices form groups? Why the mathematical theory of groups is the basis for the search for invariants of physical theories? Why there are many equivalent forms of the Dirac electron equation that transform into each other through formal transformations of matrices and the wave function? Etc..

The understanding of the fact that "quantum mechanics is not a theory, but rather a framework, within which we believe any correct theory must fit", cause the desire to construct within the framework of existing theory the completely axiomatic theory of elementary particles.

4.2. Is it possible to move to a different paradigm?

A question arises, of whether the contemporary quantum field theory is already on that stage, when it can be formulated axiomatically (Smilga, 2001):

"*In his well-known popular lectures R. (Feynmann, 1964) reflects on the way physical theories are built up and distinguishes two such ways or, rather, two stages in the process of their construction: (i) the "Babylonian" stage and (ii) the "Greek" stage.*

It is not difficult to guess that the term "Babylonian" refers to ancient Babylon and the corresponding physical theory is just, geometry. A Babylonian geometer (the words "mathematician" or "physicist' were not yet coined) knew many facts about circles, triangles, and other figures, and his understanding was not purely empirical because he could also relate different such facts with each other… In other words, his theory described the observed experimental facts well and had direct practical applications.

Our Babylonian colleague was lacking, however, a, consistent structured system in which a set of basic simple facts are chosen as axioms and all others are rigorously derived as theorems… Feynman writes that a modern physicist is a Babylonian rather than a Greek in this respect: he does not care too much about Rigor, and his God and ultimate Judge is Experiment.

Strictly speaking, this is not quite correct. Some branches of classical and also of quantum physics have now quite reached the Greek stage.

Regarding … quantum field theory in general, we are living now in interesting times when we go over from the Babylonian to the Greek stage."

Therefore, we can not exclude an opportunity of existence of other paradigm, which are not breaking the mathematical apparatus of quantum mechanics, but give the essentially other theory. "Is it possible to make differently?" - the analysis of this question from known followers of de Broglie (Andrade and Loshak, 1972) leads to following statement of a question:

"From the point of view of the sensible scientific approach, here there is no talk about whether postulates of the Copenhagen school correct or false are. The discourse goes simply about that any philosophical postulates have itself no evidential force, even if their logic connection with quantum mechanical calculations was perfect and the great discoveries on its basis were made. Hence, we should set for ourselves a problem: to establish, whether it is possible, proceeding from other postulates, to construct other interpretation of quantum mechanics and, thus, to come to the theory, which are distinct from those, which we know, and bringing new results. In other words, whether it is possible to make differently or even better?

From the most general point of view this question seems quite pertinent and it would be very much desirable to answer it so that, since no way should remain without use, the similar enterprise will justify the efforts, spent for it ".

As examples of successful physical axiomatic theories serve, e.g., Newton's mechanic and classical electrodynamics. In these theories on the basis of several postulates (or, which is the same, axioms) all formulas, necessary for calculating of the physical values in these area of science, are derived.

We propose as such a theory to consider the nonlinear quantum field theory. In framework of this theory, it can be shown that all the peculiarities of modern quantum field theory arise due to the fact that it is artificially treated as a linear theory. The mathematics of the nonlinear theory in the linear approximation is identical to the mathematics of existing QFT.

At the same time, all abovementioned features of modern quantum field theory in the nonlinear theory have a natural physical explanation and do not require artificial interpretations. Moreover, it appears that all the items of the Copenhagen interpretation are a mathematical consequence of the theory itself, thus,. justifying Andrade and Loshak's hope.

For simplicity and ease of the comparison with existing quantum field theory, we will consider only the quasi-linear representation of the nonlinear theory.

We will present here very brief results of this theory, referring to the details and proofs in the complete theory (the latest, most detailed version of the theory is published in the on-line journal «Prespacetime Journal" http://prespacetime.com/)

5.0. The axiomatic nonlinear quantum field theory (short review)

In the present theory (i.e., nonlinear quantum field theory – NQFT) the quanta of electromagnetic (EM) waves are introduced as massless boson strings of Compton wavelength scale. It is shown that at curling up of these strings within the strong electromagnetic field the closed strings, corresponding to the massive non-linear waves - solitons, are formed. Note that this curling up is similar to the transformations of the gauge type. The peculiar solitons, which are the constituents of this theory, are identical with the objects of Standard Model theory. In particular they have masses, can be only in two states – bosonic and fermionic, can have positive and negative charges, etc. It is shown that the equations of this theory fully coincide with quantum field theory equations. The theory initiates the question, whether between the modern string theory and Standard Model theory some connection exists?

5.1. Introduction. The string theory of Planck's length

String theory was built as a unified theory that incorporates quantum field theory and general relativity. String theory replaces the basic principle of point-like particles of quantum field theory with the idea that the elementary excitations of our universe are not point-like particles but strings of Planckian length 10^{-33} cm. They are little lines of energy, and when one tries to divide them up, they just form new little stretches of energy. This approach, from one side, makes it possible to avoid such difficulty of the quantum field theory as renormalization. On the other side there are no objections to thinking of the elementary constituents of nature as string-like objects because of the Planck length is so small that cannot be observed in experiments.

The main postulates of the initial string theory of the Planck scale are the following. In nature there are some one-dimensional non-local objects, which are characterized by the vibration energy -strings. The simplest strings are the open mass-free boson strings. The closed strings are formed by bending of the open strings as objects with different number of loops (fig. 5.1):

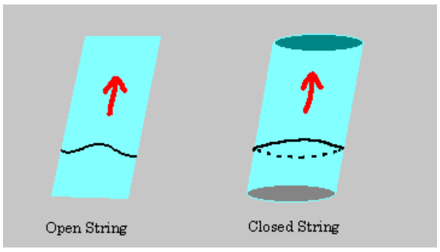


Fig. 5.1.

Moreover, closed strings can be divided into other closed strings, or two of these can be combined in one closed string (fig. 5.2):

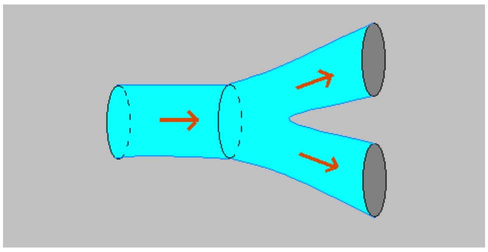


Fig. 5.2.

5.2. The low-energy EM string of Compton wave length

In accordance with the Planck and Einstein theory of photon (Frauenfelder and Henley, 1974) a monochromatic electromagnetic (EM) wave consists of N monoenergetic photons, each of which have zero mass, energy ε, momentum $\vec{p}$, and wavelength λ, whose values are mutually unambiguously connected among themselves: $\varepsilon = \hbar\omega$, $\vec{p} = \hbar\vec{k}$, $\varepsilon = cp$, (where $\vec{k} = \vec{k}^0/\lambdabar$ is wave vector, $\lambdabar = \lambda/2\pi$ is reduced wavelength). The number of photons in the EM wave is such, that their total energy $\varepsilon_{full} = N\varepsilon = N\hbar\omega$. Photons are bosons, and coherent photons are able to be condensed in EM wave (e.g., laser beam), which has a certain frequency.

As it is known, in framework of QED (Akhiezer and Berestetskii, 1965) for construction of the theory of the photons and their interaction with other particles the Maxwell equations along with the relationship $\varepsilon = \hbar\omega$ are sufficient. To obtain the photon wave function the second order wave equations for EM field vectors $\vec{E}$ and $\vec{H}$ are used.

Factorizing the wave equation to the equations for retarded and advanced waves (Akhiezer and Berestetskii, 1965) , we receive two equations of first degree regarding the function f_k, which adequates to a wave vector k and is some generalization of the EM field vectors. The equation for this function is equivalent to the Maxwell-Lorentz equations.

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

Actually, the $f(\vec{r},t)$ function is not defined by the value of the field $\vec{E}(\vec{r},t)$ 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 the value $|f(\vec{r},t)|^2$ will not have the sense of probability density to find a photon in the given point of coordinate space.

5.3. Electromagnetic string hypothesis

Being guided by above results let us introduces the formal representation of photon as the EM string. *Note that since the photon characteristics are mutually unambiguously connected among themselves, we can insist that photon has only one own independent characteristic.* Then, keeping in mind the wavelength of photon , it is possible to say that photon in framework of QFT is conditionally one-dimensional formation.

The one-dimensional object, which, on the one hand, obeys the wave equation, and on the other hand is not point, in physics is referred to as a ***string*** (it is clear, of course, that this supposition can have no relationship to the real structure of a photon).

These allows us to introduce the following postulate:

Tthe fundamental particle of an EM field - photon - is the open relativistic EM string with one wavelength size, which corresponds to its energy according to Planck's formula.

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

Since a photon is a boson, we can expect that the photon string theory will be cognate to the initial modern string theory, in which the boson strings are the source material, from which the closed strings, i.e. the elementary particles, are formed.

Thus, we can suppose that ***under certain external conditions the EM string can start to move along the closed curvilinear trajectory, forming the closed strings (or in other words, solitons), which can be considered as EM elementary particles.***

Note, that in the case of the photon string the introduction of such postulate is not needed. Actually, the bending of a trajectory of an EM wave in the strong EM field follows already from the Maxwell-Lorentz theory.

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

5.4. Comparison of EM strings theory with the modern theory of strings

Let's compare the EM- string theory with modern theory of strings, as it is described by one of the founders of this theory (Schwarz, 1987):

"*Strings can have two various topology, which refer as opened and closed. The open strings are pieces of lines with free ends, while the closed strings represent loops with topology of a circle and have no free ends…*

… Various quantum-mechanical excitation (normal modes) of string for each solution of the given theory of strings are interpreted as a spectrum of elementary particles...

The theory of strings gives the uniform approach to the rich world of the elementary particles, considered as a various modes of excitations of a unique fundamental string ".

Elementary particles are simultaneously waves, and all equations of the quantum field theory are wave equations. This cannot be abolished by any new theory, since SM is very well checked experimentally.

The theory of strings is represented as the generalization of the theory of elementary particles. Therefore it must result in the wave equations. In other words it must have the Lagrangian and action function, which correspond to wave equations.

In the simplest case of real relativistic wave the equation of motion is written as:

$$\frac{1}{c^2}\ddot{\psi} + \Delta\psi = 0$$

The Lagrangian, which corresponds to it, is:

$$\bar{L} = -\frac{1}{2}c^2 \sum_{\nu} \frac{\partial\psi}{\partial x_\nu}\frac{\partial\psi}{\partial x_\nu} \equiv \frac{1}{2}c^2 \partial_\nu \psi \; \partial^\nu \psi$$

and also the function of action:

$$S = -\frac{1}{2}c^2 \int_t dt \int_V \partial_\nu \psi \; \partial^\nu \psi \; dx$$

The strings are some energy formations, which do not attached to any concrete physical objects. But in nature there is no energy without matter. In the elementary particle's theory the objects, which carry energy, are de Broglie's waves, described by ψ - function.

Relativistic Lagrangian of the motion of point particle is used as initial Lagrangian of the theory of strings (Larranaga, 2003). On the basis of the last the action function of the Nambu-Goto is introduced into the theory:

$$S(x) = -\frac{1}{2}\int d\sigma \int d\tau \sqrt{\dot{x}^2 x'^2 - (\dot{x}\cdot x')^2}$$

To pass to quantum representation the square root of the Nambu-Goto action is recorded in the linear form. The equivalent action of Polyakov, introduced on this basis, is the initial Lagrangian of the string theory:

$$S(x,\gamma) = -T\int d\sigma \int d\tau \sqrt{-\gamma}\gamma^{ab}\partial_a x^\mu \partial_b x^\nu \eta_{\mu\nu}$$

Obviously, in order to pass to real elementary particles within the framework of SM we must examine the functions x^μ as the wave function ψ. Then as we see the above action becomes similar to the action of the wave equation.

The theory of strings has many interesting and important possibilities, but it cannot be verified because of smallness of the Planck length scale (at least until now its conclusions have not been confirmed on the hadron collider).. At the same time the modern elementary particle theory – Standard Model – is very well checked experimentally. Below we will show that there is the low-energy string theory of Compton's wavelength scale, which coincides with the Standard Model theory in its results. The proposed theory include the gravitational interaction (not discussed here).

5.5. Axiomatic basis of the nonlinear quantum field theory (NQFT)

The axiomatic basis of the proposed theory is composed by 6 postulates, which do not contradict to the results of contemporary physics. Note that postulate 5 is the basis for the formation of massive elementary particles as nonlinear quantum electromagnetic fields.

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

2. The Plank's-Einstein's postulate of quantization of electromagnetic waves: ***the electromagnetic waves are the superposition of the elementary wave fields named photons, having the certain energy, momentum and zero rest mass.***

3. Postulate of dualism of photons: ***photons exist as real independent objects, which have***

the wave properties ***described by the wave equation following from Maxwell-Lorentz equations,*** **and quantum properties,** ***described by quantization rules*** $\varepsilon = \hbar\omega$, $\vec{p} = \hbar\vec{k}$. (where ε is photon energy, $\vec{p}$ is momentum, $\vec{k}$ is wave vector, ω is circular frequency, $\hbar$ is the Planck constant).

4. Postulate of EM string: ***Within the framework of the present theory the fundamental particle of an EM field - the photon - can be described as a relativistic EM string of one wavelength size, which corresponds to its energy according to Planck's formula.***

5. Postulate of formation of massive particles: ***within the framework of the present theory under the certain external conditions the EM string can start to move along the closed curvilinear trajectory, forming the elementary particles.***

6) The postulate of superposition of EM strings: ***in the general case elementary particles are the superposition of elementary closed EM strings.***

Let us use the abovementioned postulates to obtain the equations of each type of elementary particles. (see in details the book (Kyriakos, 2009) and specified articles that are freely available)

5.6 Equation of photon

(see in details (Kyriakos, 2010))

Using the postulates 1 and 3, we can obtain from Maxwell's equations the wave equation of the photon. An electromagnetic (EM) waves propagating in any direction can be represented by two independent waves with plane polarizations or one wave with circular polarization. In both cases these waves contains only four field vectors. For example, in the case of a direction along the y-axis, we obtain the wave equation

$$\left[\left(\hat{\alpha}_o\hat{\varepsilon}\right)^2 - c^2\left(\hat{\vec{\alpha}}\ \hat{\vec{p}}\right)^2\right]\Phi = 0\,, \qquad (6.1)$$

where $\hat{\varepsilon} = i\hbar\,\partial/\partial t$, $\hat{\vec{p}} = -i\hbar\vec{\nabla}$ are the operators of energy and momentum; $\hat{\alpha}_0$; $\hat{\vec{\alpha}}$; $\hat{\beta} \equiv \hat{\alpha}_4$ are Dirac matrices, while Φ is certain matrix; in this case:

$$\Phi = \begin{pmatrix} \mathrm{E}_x \\ \mathrm{E}_z \\ i\mathrm{H}_x \\ i\mathrm{H}_z \end{pmatrix},\ \Phi^+ = \left(\mathrm{E}_x \quad \mathrm{E}_z \quad -i\mathrm{H}_x \quad -i\mathrm{H}_z\right), \qquad (6.2)$$

where $\vec{\mathrm{E}}$ and $\vec{\mathrm{H}}$ are the vectors of strength of electrical and magnetic fields)

The harmonic functions are the solution of this equation:

$$\begin{cases} \vec{\mathrm{E}} = \vec{\mathrm{E}}_o e^{-i(\omega t + ky)} + \vec{\mathrm{E}}_o^* e^{i(\omega t - ky)} \\ \vec{\mathrm{H}} = \vec{\mathrm{H}}_o e^{-i(\omega t + ky)} + \vec{\mathrm{H}}_o^* e^{i(\omega t - ky)} \end{cases}, \qquad (6.3)$$

where ω and $\vec{k}$ are quantified according to postulate 3: $\omega = \varepsilon/\hbar$ and $\vec{k} = \vec{p}/\hbar$.

Factorizing of (6.1), we will obtain the system:

$$\begin{cases} \Phi^+\left(\hat{\alpha}_o\hat{\varepsilon} - c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) = 0 \\ \left(\hat{\alpha}_o\hat{\varepsilon} + c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right)\Phi = 0 \end{cases}, \qquad (6.4)$$

These equations, taking into account the quantization of energy and momentum, are the known quantum equations of photon, equivalent to one equation (6.1). The physical sense of these equations is revealed with the substitution of expressions (6.2). As a result we obtain Maxwell's equations for the advanced and retarded waves:

$$\left\{\begin{array}{l}\left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_x}{\partial t}-\frac{\partial \mathrm{H}_z}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_z}{\partial t}-\frac{\partial \mathrm{E}_x}{\partial y}=0\end{array}\right.\\ \left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_z}{\partial t}+\frac{\partial \mathrm{H}_x}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_x}{\partial t}+\frac{\partial \mathrm{E}_z}{\partial y}=0\end{array}\right.\end{array}\right., \quad (6.5') \qquad \left\{\begin{array}{l}\left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_x}{\partial t}+\frac{\partial \mathrm{H}_z}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_z}{\partial t}+\frac{\partial \mathrm{E}_x}{\partial y}=0\end{array}\right.\\ \left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_z}{\partial t}-\frac{\partial \mathrm{H}_x}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_x}{\partial t}-\frac{\partial \mathrm{E}_z}{\partial y}=0\end{array}\right.\end{array}\right., \quad (6.5'')$$

which confirms the EM nature of photon. For waves of any other direction the same results can be obtained by cyclic transposition of indices, or by a canonical transformation of matrices and wave functions.

In the case of plane polarization there are two separate photons, that move along the y-axis (in our case with the vectors $\mathrm{E}_x, \mathrm{H}_z$ and $\mathrm{E}_z, \mathrm{H}_x$), which are described by two independent systems of equations:

$$\left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_x}{\partial t}\mp\frac{\partial \mathrm{H}_z}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_z}{\partial t}\mp\frac{\partial \mathrm{E}_x}{\partial y}=0\end{array}\right., \ (6.6') \ \text{and} \ \left\{\begin{array}{l}\frac{1}{c}\frac{\partial \mathrm{E}_z}{\partial t}\pm\frac{\partial \mathrm{H}_x}{\partial y}=0\\ \frac{1}{c}\frac{\partial \mathrm{H}_x}{\partial t}\pm\frac{\partial \mathrm{E}_z}{\partial y}=0\end{array}\right., \quad (6.6'')$$

Further let us show, how the mass of elementary particles is generated.

5.7. Equation of intermediate boson ("massive photon")

In the framework of nonlinear QFT particles acquire mass through an intermediate massive boson. The last is generated with the rotation transformation of EM field of EM string. We will use the postulates 4 - 5 and produce the rotation transformation $\hat{R}$ of photon fields Φ :

$$\hat{R}\Phi \rightarrow \Phi', \qquad (7.1)$$

where Φ' is the new wave function, which appears after the transformation of the rotation (see fig 5.3):

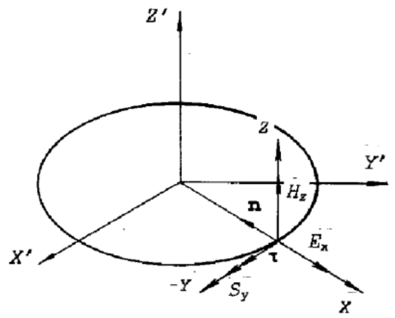


Fig 5.3

$$\Phi' = \begin{pmatrix} E'_x \\ E'_z \\ iH'_x \\ iH'_z \end{pmatrix} = \begin{pmatrix} \Phi'_1 \\ \Phi'_2 \\ \Phi'_3 \\ \Phi'_4 \end{pmatrix}, \tag{7.2}$$

where $(E'_x,\ E'_z,\ H'_x,\ H'_z)$ are the vectors of the electromagnetic field, which appear after the rotation transformation and are the wave functions of the new particle within the framework of quantum theory.

Let us examine the EM wave, which moves along the circular path, so that vectors $\vec{E}, \vec{H}$ and Poynting's vector $\vec{S}$ move as shown in the figure 1:
Displacement current in equations (6.5) is determined by the expression:

$$j_{dis} = \frac{1}{4\pi}\frac{\partial \vec{E}}{\partial t}, \tag{7.3}$$

The electric field vector of the expression (7.3), during the motion along the curvilinear trajectory, can be recorded in the form:

$$\vec{E} = -E \cdot \vec{n}, \tag{7.4}$$

where $E = |\vec{E}|$, and $\vec{n}$ is the unit vector of the normal to the curve. After differentiation the displacement current of the plane wave, which moves along the ring, can be recorded in the form:

$$\vec{j}_{dis} = -\frac{1}{4\pi}\frac{\partial E}{\partial t}\vec{n} + \frac{1}{4\pi}\omega_p E \cdot \vec{\tau}, \tag{7.5}$$

where $\omega_p = \dfrac{\varepsilon_p}{\hbar} = \dfrac{m_p c^2}{\hbar} \equiv cK$, and $m_p = \varepsilon_p / c^2$ is a mass, which corresponds to photon energy ε_p; $\vec{j}_n = \dfrac{1}{4\pi}\dfrac{\partial E}{\partial t}\vec{n}$ and $\vec{j}_\tau = \dfrac{\omega_p}{4\pi} E \cdot \vec{\tau}$ are the normal and tangential components of displacement current of "nonlinear" EM waves, respectively.

A more general expression can be obtained, describing rotation in the curvilinear geometry of Riemann. In this case it occurs that the currents are determined by the connections of field, i.e., by the symbols of Ricci (or, in the most general case, by Christoffel symbols)

The physical sense of the generation of mass consists of the following. At the moment of rotation transformation, a self-interaction of own fields occurs in the photon (mass-free boson). Due to this fact the photon fields revolve in the small region of space. In this case its energy does not move from infinity to infinity with the speed of light, but it is locked in a small space region. This concentration of photon energy is a massive particle, one of characteristics of which is the value $m = \varepsilon_p / c^2$.

It is remarkable that in nonlinear QFT the mass does not appear as primary characteristic, but as the ratio of energy to the square of the speed of light. Its property - to be coefficient in the mechanical momentum, which determines the inertia of particle - can be shown by the Ehrenfest theorem.

Because of the rotation, this mass assigns an angular momentum of particle, i.e. spin (in this case, equal to 1). Simultaneously the tangential current appears. Since in this case the current is sinusoidal, electrical charge of "massive photon" is equal to zero.

As a result of the transformation of rotation we will obtain the equation of intermediate boson ("massive photon"):

$$\left(\hat{\alpha}_o\hat{\varepsilon} - c\hat{\vec{\alpha}}\cdot\hat{\vec{p}} - \mathrm{K}\right)\left(\hat{\alpha}_o\hat{\varepsilon} + c\hat{\vec{\alpha}}\cdot\hat{\vec{p}} + \mathrm{K}\right)\Phi' = 0, \tag{7.6}$$

Or, taking into account the value K (see above), we will obtain this equation in form:

$$\left(\hat{\varepsilon}^2 - c^2\hat{\vec{p}}^2 - m_p^2c^4\right)\Phi' = 0, \tag{7.7}$$

The Lagrangian equation (7.7) can be recorded in the form:

$$L = D_\mu\Phi'^+ D^\mu\Phi' = \partial_\mu\Phi'^+ \partial^\mu\Phi' - \Phi'^+ m_p^2c^4\Phi', \tag{7.8}$$

where the term, which directly contains the mass of intermediate boson, can be represented as follows

$$\Phi' m_p^2c^4\Phi' = \frac{\Delta\tau}{8\pi}\Phi'\left[\left(\Phi'^+\hat{\alpha}_0\Phi'\right)^2 - 4\left(\Phi'^+\hat{\vec{\alpha}}\Phi'\right)^2\right]\Phi', \tag{7.9}$$

and describes in the nonlinear theory the energy of self-interaction. It is not difficult to see that the expression (7.9) has a similarity with Higgs's potential.

In the following section we will examine the question of the generation of massive charge leptons: electron and positron

5.8. Equations of electron and positron

(see in details (Kyriakos, 2004))

In the case of the plane-polarized initial photon the equation (7.7) gives the possibility to obtain two oppositely charged particles with half-integral spin of the type of electron and positron.

For this, we will make, conditionally speaking, the breaking of the intermediate boson symmetry. Multiplying equation (7.7) to the left on Φ'^+ and making factorizing, we will obtain the equations of two particles, which are located in the field of each other:

$$\left[\left(\hat{\alpha}_o\hat{\varepsilon} + c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) + \hat{\beta}\ m_pc^2\right]\psi = 0, \tag{8.1'}$$

$$\psi^+\left[\left(\hat{\alpha}_o\hat{\varepsilon} - c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) - \hat{\beta}\ m_pc^2\right] = 0, \tag{8.1''}$$

Here $\psi = \begin{pmatrix} E_x \\ E_z \\ iH_x \\ iH_z \end{pmatrix} \equiv \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \end{pmatrix}$ is lepton wave function, which corresponds to electromagnetic field after the breakdown of intermediate boson (this ψ-function is not the vector, but a so-called - by L.D. Landau - semi-vector, i.e. spinor).

In the simplest case of the production electron-positron pair $m_p = 2m_e$, and from (8.1) we have:

$$\left[\left(\hat{\alpha}_o\hat{\varepsilon} + c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) + 2\hat{\beta}\ m_ec^2\right]\psi = 0, \tag{8.2'}$$

$$\psi^+\left[\left(\hat{\alpha}_o\hat{\varepsilon} - c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) - 2\hat{\beta}\ m_ec^2\right] = 0, \tag{8.2''}$$

It is obvious that in order to become free, the electron and positron must spend energy. It is not difficult to calculate, that during their removing from each other an amount of energy must be spent, equal to the amount, which is necessary for the formation of particle themselves. The external field of particles arises due to this process. Using a linear writing of the energy-momentum conservation law, we will obtain for the external field of the particle:

$$\hat{\beta}\ m_ec^2 = -\varepsilon_{ex} - c\hat{\vec{\alpha}}\ \vec{p}_{ex} = -e\varphi_{ex} - e\hat{\vec{\alpha}}\ \vec{A}_{ex}, \tag{8.3}$$

where “ex” indicates “external”; then, substituting (8.3) in (8.2), we obtain Dirac's equation with the external field:

$$\left[\hat{\alpha}_0\left(\hat{\varepsilon} \mp \varepsilon_{ex}\right) + c\hat{\vec{\alpha}} \cdot \left(\hat{\vec{p}} \mp \vec{p}_{ex}\right) + \hat{\beta}\ m_e c^2\right] \psi = 0\,, \tag{8.4}$$

At a sufficiently great distance between the particles, when these fields are not important, we obtain Dirac's equations for the free particles - electron and positron:

$$\left[\left(\hat{\alpha}_o \hat{\varepsilon} + c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) + \hat{\beta}\ m_e c^2\right] \psi = 0\,, \tag{8.5'}$$

$$\psi^+\left[\left(\hat{\alpha}_o \hat{\varepsilon} - c\hat{\vec{\alpha}}\ \hat{\vec{p}}\right) - \hat{\beta}\ m_e c^2\right] = 0\,, \tag{8.5''}$$

5.9. Physical sense of wave function and its normalizing

5.9.1. Normalization of the wavefunction in quantum theory

In quantum mechanics and quantum field theory, the state of the system is represented by a complex wave function $\psi(\vec{r},t)$. This wave function evolves in time according to equation of each elementary particle (for electron this is Schrödinger's of Dirac equations, etc.)

According to Born's rule the probability density of finding a particle in a certain place $P(\vec{r},t)$ is proportional to square of its absolute value: $p(\vec{r},t) = \left|\psi(\vec{r},t)\right|^2$. The Born rule tells us that the integral

$$P(t) = \int_{\Delta\tau} \left|\psi(\vec{r},t)\right|^2 d\tau\,, \tag{9.1}$$

(where $d\tau$ is element of space volume), corresponds to a probability of finding a particle in a certain space volume $\Delta\tau$. And so it follows that the integral $\int \left|\psi(\vec{r},t)\right|^2 dx$ over all possible states must be 1:

$$P(t) = \int_{-\infty}^{+\infty} \left|\psi(\vec{r},t)\right|^2 d\tau = 1\,, \tag{9.2}$$

That's called normalization of the wave function. Normalization is just scaling $\psi(\vec{r},t)$ by a constant to make sure this integral is indeed unity.

5.9.2 Wave function normalization in NQFT

In the NTEC, the wave function has a physical meaning: it is the strength of a nonlinear electromagnetic field. Mathematically, it is a complex quantity. Obviously, in this form it is unnormalized.

It is not difficult to show that, with appropriate normalization, this wave function can characterize the position of particle in accordance with the Born rule

We will use the indices '*n*' and '*un*' as normalized and unnormalized wave functions, respectively. The value

$$\psi^+_{\mathrm{un}}(\vec{r},t) \cdot \psi_{\mathrm{un}}(\vec{r},t) = \left(\vec{E}^2 + \vec{H}^2\right)/8\pi = \rho_\varepsilon(\vec{r},t)$$

is the energy density of the electron field $\rho_\varepsilon(\vec{r},t)$. The energy density is equal to energy, enclosed in some volume, divided by this volume: $\rho_\varepsilon = \Delta\varepsilon/\Delta\tau$

If we divide the non-normalized function by the energy ε_0 or mass of the particle m_0 in accordance with the Einstein formula $\varepsilon_0 = m_0 c^2$, we get a normalized function:

$$\psi_n(\vec{r},t) = \frac{\psi_{\mathrm{un}}(\vec{r},t)}{\sqrt{8\pi\varepsilon}} = \frac{\psi_{\mathrm{un}}(\vec{r},t)}{\sqrt{8\pi mc^2}}\,, \tag{9.3}$$

Then the probability density of finding an electron at a given point of space-time will be expressed as follows:

$$p(\vec{r},t)=\psi_{nor}^{+}\psi_{nor}=\frac{\psi_{\mathrm{unn}}^{+}\psi_{\mathrm{unn}}}{8\pi\varepsilon}=\frac{\psi_{\mathrm{unn}}^{+}\psi_{\mathrm{unn}}}{8\pi mc^{2}}, \qquad (9.4)$$

In fact, the normalization expresses the affixment of the particle to self-energy or mass of this particle. Indeed, the integral

$$\int_{0}^{\infty}\psi_{\mathrm{un}}^{+}\psi_{\mathrm{un}}d\tau=\varepsilon, \qquad (9.5)$$

determines the energy of particle. The main normalization requirement is obtained by going over to a normalized function.

$$\int_{0}^{\infty}\psi_{n}^{+}\psi_{n}d\tau=1, \qquad (9.6)$$

Thus, the absence of physical meaning of the wave function in quantum theory based on the fact that in the quantum theory the energy of an elementary particle is taken as a dimensionless unit. Clearly, this imposes no requirement to the particle to be point.

5.10. Equation of the massive neutrino

(see in details (Kyriakos, 2005))

It can be easy shown that from the circularly polarized photon field, massive neutrino is formed with all its known properties. It is noticeable that in this case the helicities of neutrino and antineutrino are mutually opposite and no transformation can change this property. In other words, the neutrino has always the left spirality, and antineutrino – right spirality (note that in SM this property is not explained and is accepted as a postulate).

5.11. Equation of the hadrons

(see in details (Kyriakos, 2011))

The formation of different hadrons is also connected with the described characteristics of leptons. According to the postulate 6, wave fields can form superpositions. It is possible to show that with the superposition of elementary fields, which are equivalent to leptons, different hadrons can be formed, which are described by Yang–Mills equation. Moreover, by the superposition of two lepton-like fields mesons can be formed, by the superposition of three lepton-like fields - baryons..

6.0. The non-linear quantum field theory without formulas

Photon as part of EM wave (i.e. as EM-string) has the following graphic representation (which, note again, doesn't have any connection with the unknown to us real photon structure) (see fig.6.1).

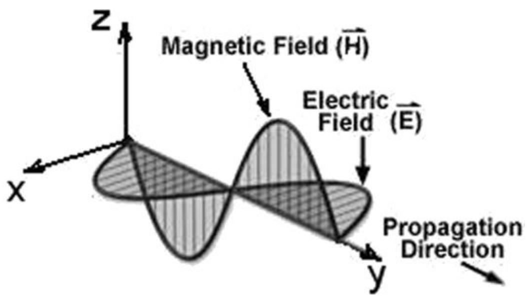


Fig.6.1

Let's consider under accepted postulates the production of elementary particles from EM-string. We shall begin with the most simple particle - electron. Let's consider the reaction of electron-positron pair production in nuclear field (see fig. 6.2; compare with fig. 5.2):

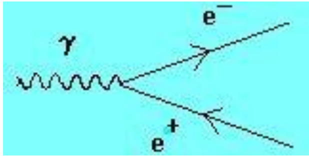


Fig.6.2

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 5 for particle formation a photon should to be twirled into a ring, and according to fig. 6.2 it should then be divided in two halfs, 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. 6.2 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. 6.3).

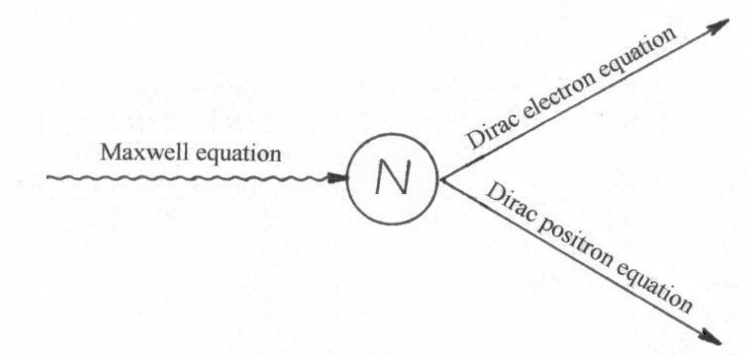


Fig. 6.3

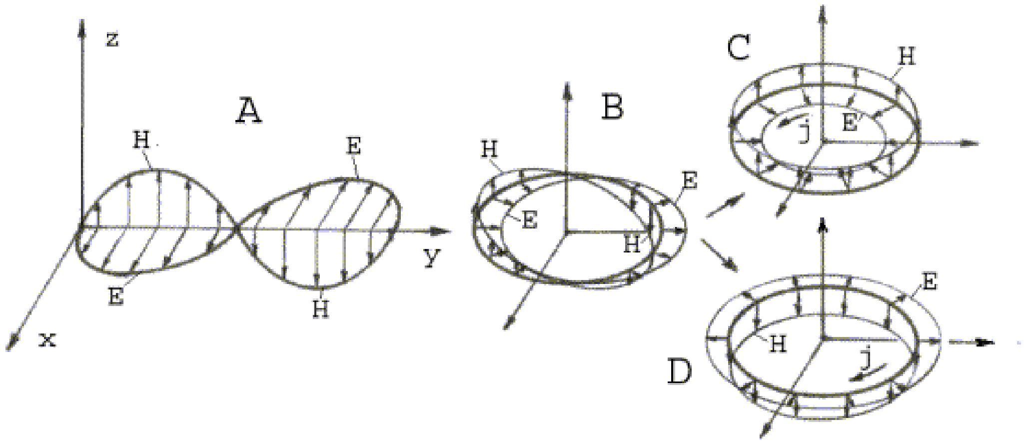
Thus, according to our scheme it follows that the Dirac equations are the field equations each of two parts of the twirled EM wave.

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):



(Fig. 6.4)

Thus, conditionally speaking, from one vector particle we receive two semi-vector particles, (two spinors) which according to fig. 6.4 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, NQFT 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. 6.5):

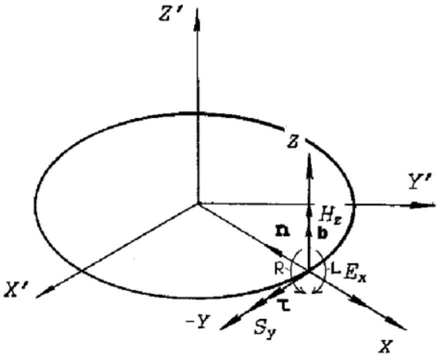


Fig. 6.5

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 NQFT 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 (wave-corpuscular dualism of de Broglie). Actually, NQFT 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 as the medium with the big refraction index, in 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 (as boson) has integer spin , the twirled semi-photons have spin half (i.e., they are fermions), we automatically receive an explanation of division of all elementary particles into bosons and fermions.

6. It is easy to see, that the fig. 6.4 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.

7. In the theory of static spherical electron of Lorentz classical theory there are no the electromagnetic forces, capable to constrain the repulsion of electron parts from each other and therefore it is necessary to enter Poincare's forces of non electromagnetic origin. In our case 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 of the same type as neutrino and antineutrino, which are described by Dirac bispinor equation. Figure 6.6 shows the distribution of the electric field connected with the circularly polarized wave of the positive (right) and negative (left) helicity (fig. 6.6):

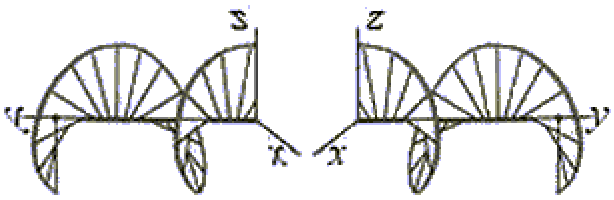


Fig. 6.6

The twirled half-periods of such photons give the EM particles with inner helicity (fig. 6.7).

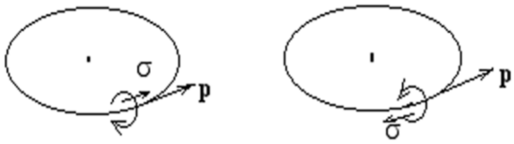


Fig. 6.7.

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. 6.8; see also animation of Moebius strip in http://mathworld.wolfram.com/MoebiusStrip.html). This property of the EM-lepton vector corresponds to the same property of wave function of Dirac lepton theory.

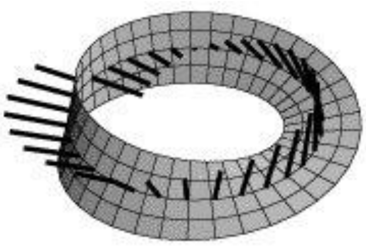


Fig. 6.8

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 NQFT 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. 6.9):

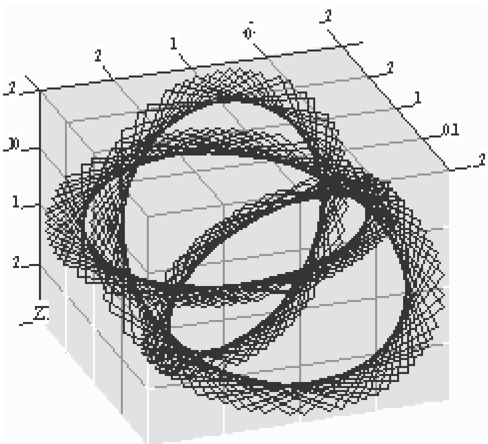


Fig. 6.9

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.

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

Within the framework of NQFT 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 NQFT 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 NQFT, 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 NQFT 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.

Accordingly with QED the electron mass and charge in equation (8.5) is “bare”. This indicates that here is not examined the polarization of the physical vacuum and not considered the screening of electron in the physical vacuum. During this polarization both the charge and the size of the electron must decrease to the values, which characterize the real electron. How is it possible to estimate these real values?

As is known, (Georgi, 1982) due to the screening in the physical vacuum electron charge must be reduced in the same ratio as fine structure constant. Obviously the same take place in case of electron size. It can be shown that an experimental radius must be equal to: $r_c \cdot \alpha = e^2/mc^2 = r_0$ where $\alpha = e^2/\hbar c$ is the fine structure constant. Thus this gives as a real radius of the electron the classical radius r_0. This fact explains also, why there is such relationship as $r_0/r_c = \alpha \approx 1/137$: we can suppose that during polarization of physical vacuum the mass, charge and size of the electron decrease approximately in 137 times. Then it is clear that in the cross-sections of interactions the classical radius appears precisely because it is the dimensional characteristic of an electron

Of cause, such representation do not disrupt the results of QED. 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 "Zittertbewegung" - "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 "Zittertbewegung" with rotation of a semi-photon fields (see fig. 6.4) these "hidden" parameters cease to be "hidden".

Indeed, the field of an electron always moves at the speed of light. According to the forming method, the radius of motion (the amplitude of the motion) is equal to half the Compton's wavelength, and the rotation frequency is equal to the linear velocity divided by the radius of motion, as it is supposed to be in a circle motion.

Thus, the problem of "hidden parameters" is removed by the fact that we "discover" them or, better to say, find them in known equations and their solutions

In this connection one additional question can arise: is it possible to exclude the renormalization from NQFT?

It should be noted that in the quantum field theory there are two forms of renormalization.

One renormalization procedure is necessary, when we consider the polarization of vacuum, when we pass from “bare” charges to the real. This renormalization is physical and necessary in any theory.

The other renormalization procedure is connected with the elimination of infinities, which appear as a result of the pointlike representation of particles. This renormalization can be eliminated in NQFT.

Let us note that already in the nonlinear classical electromagnetic field theory the possibility of describing of the same particle as point and nonpoint exists and is known for a long time (see details in the nonlinear electron theory of Born-Infeld).

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