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On the Origin of Conceptual Difficulties of Quantum Mechanics

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Abstract

It is the matter of fact that quantum mechanics operates with notions that are not determined in the frame of the mechanics' formalism. Among them we can call the notion of "wave-particle" (that, however, does not appear in both classical and high energy physics), the probabilistic interpretation of the Schrödinger wave ψ -function and hence the probability amplitude and its phase, long-range action, Heisenberg's uncertainty principle, the passage to the so-called operators of physical values, etc. Orthodox quantum mechanics was constructed as a physical theory developed in the phase space of the mentioned notions. That is why the formalism of quantum mechanics is aimed only at detailed calculations of the stationary states of the energy of the quantum system studied and is not able to describe a real path running by the system in the real space; instead, the formalism gives an averaged probabilistic prediction. Thus, if we are able to develop quantum mechanics in the real space, an option to clarify all the difficulties associated with the above notions would appear. Such a theory of quantum mechanics developed in the real space in fact has recently been constructed by the author. The theory started from deeper first principles, namely, from the consideration of the notion of a 4D space-time. So, the notion of fundamental particle, the principles of the motion of a particle and other characteristics have been made clear. The theory, rather a submicroscopic one, is characterized by short-range action that automatically means the introduction of a new kind of carriers, i.e. carriers of the quantum mechanical force. The existence of the carriers called "inertons" (because they carry inert properties of matter) has indeed been verified in a number of experiments.

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1 Dominant views on the foundations of quantum mechanics

The founders of quantum mechanics raised some problems regarding its conceptual difficulties such as the description of particles by using a probabilistic wave ψ -function, the ψ -function collapsing at the measuring, Bohr's notion of "complementary" [1], Schrödinger's cat (i.e., the problem of transforming a set of microscopic states into a particular macroscopic state) and entanglement [2], Einstein-Podolsky-Rosen (EPR) paradox [3], etc. Since that the subject still continue to disturbance inquiring minds of researchers and nowadays they put the study on nonlocality of quantum mechanics, quantum paradoxes, entanglement and decoherence, and quantum teleportation in the forefront of the fundamental science.

Among recent research on misconceptions regarding quantum mechanics one can mention the paper by Bush [4] in which he touches a number of conceptual and mathematical problems in the fundamentals and the study by Styer [5] in which he lists a series of commonly held misconceptions such as "energy eigenstates are the only allowed states", "the wave is dimensionless", etc. It seems that the literature on the so-called Bell inequality [6] and its validity or violation is the most extensive. Evidently that such an interest to the Bell inequality is caused by the fact that Bell's inequality is based on other postulates of the physical world than orthodox quantum mechanics prescribes.

Let us touch studies regarding the Bell theory in some detail. Muynck [7] noted that the Bell inequality was first derived for hidden-variables theories, rather stochastic theories (see, e.g. Refs. [8,7] on the hidden-variables theories) and only after that the inequality was obtained for conventional quantum mechanics. Many years ago Wigner [9] considering the problem of hidden variables also noted that we could not obtain directly their magnitudes. He noticed that the measuring the distribution of magnitudes of hidden variables still remained undetermined, or fuzzy. Therefore, hidden variables as such severe suffer from a statistical nature.

Let us write the Bell inequality following Muynck's designations [7]. In the Bell experiment either standard observable A_1 or B_1 of particle 1 is measured jointly with standard observable A_2 or B_2 of particle 2. It is assumed that observables A_1 and B_1 are incompatible, i.e. commutator $[A_i, B_j] \neq 0$, though $[A_i, B_i] = [A_j, B_j] = 0$ where $i = 1, 2$, $j = 1, 2$, and $i \neq j$. Let all observables have only values $+1$ and -1 . Then in terms of the expectation values $\langle A_i A_j \rangle$ of the correlation observables $A_i A_j$ the Bell inequality becomes

$$|\langle A_1 A_2 \rangle - \langle A_1 B_2 \rangle| \leq 2 + \langle B_1 A_2 \rangle + \langle B_1 B_2 \rangle. \quad (1)$$

Mensky [10] emphasized such major peculiarities of the objective local theory by Bell as: (i) each particle is characterized by a number of variables (in expression (1) two variables are analysed) which are possibly correlated for the two particles; (ii) the results of measurement of one particle do not depend

on whether the other particle is measured or not, and if it is, they do not depend on the result of such a measurement. Thus the Bell experiment does not suggest any quantum mechanical nonlocality.

Experimental data by Aspect and co-workers [11,12], Zeilinger's team [13] and others showed the violation of Bell's inequality (1). Many researchers were astonished at such a result. In particular, Evdokimov et al. [14] noted that the violation of Bell's inequality in quantum world was a true paradox.

Muynck [7] accounts for the Aspect's experiments by a local disturbance of the measurement results due to incompatibility of observables of the same particle, rather than of a nonlocal disturbance of one particle due to a measurement of an observable of the other particle. Muynck analyzes also the generalized inequalities and their violation by the experiments in connection with the experiments. He reasonably notes that we do not have any reason to expect that the standard Aspect experiments should satisfy the Bell inequalities, because of Heisenberg disturbance of a complicated probability. In other words, the violation of Bell's inequality is a consequence of the observables, which definitely should be caused by Heisenberg's uncertainty principle that occurred in the arms of the interferometer. So, there is no need to suppose any extension nonlocality, i.e. the influence of the measurement in one arm of the interferometer on the measurement in the other one.

Nakhmanson [15,16] directly shows weak points in the experiments by Aspect's and Zeilinger's teams. He notes that the actual experiments were far from the thought experiment by EPR and Bell, which the experimenters wished to test. Namely, in the Aspect's case the switching of conditions of registration of photons was not adiabatic and therefore it prevented any realistic connection between photons in the EPR pair. Nakhmanson wrote: "This gave rise to the legend of nonlocality of quantum mechanics, of the 'instantaneously' correlated behavior of the EPR pair, even though its constituent particles may be hundred of light-years apart". Then he continued that in the experiments by Zeilinger's team [13] the conditions of registration were governed by a random number generator and the 'randomness' was borrowed from the object of the study itself, i.e. the quantum world.

Eberly [17] has recently argued that the inequalities of the Bell type by themselves have nothing to do with quantum theory. He points out that the inequalities do not take into account that there is no physical sense to an intermediate polarization in quantum theory. However, that is the state that Bell's inequalities have included. Then Eberly stresses: "The violation of Bell's inequality is a simple mathematical result obtained by an uncomplicated counting of members of objects in clearly defined categories."

Nevertheless, the study of Bell's inequalities still continues. Mermin [18] has recently shown that some kinds of correlation (or even direct classical communication) between detectors in fact validate Bell's theorem. Golshani and Fahmi [19] asserts that the violation of Bell's inequality is not necessarily the violation of Bell's locality condition and that if there is any nonlocality in nature, it is not in the form of even more complicated inequalities studied

by the authors. The most detailed study demonstrates Zeilinger's team (see, e.g. Refs. [20-24]). They introduce, in particular, the notion of 'quantum entanglement' determining it as a feature of a composite system to have more information contained in correlations than any classical mixture of its individual constituents could ever have [22]. Working on the developing of the quantum theory of information they have proposed [23] the notion of the irreducible randomness of individual events, which together with quantum complementary and quantum entanglement have allowed them to support the nonlocality: The nonlocality for photons that never interacted has been confirmed by observing a violation of Bell's inequality by 4.5 standard deviations [24]. The result obtained is considered as an actual proof of the quantum nature of teleportation. Thus Zeilinger's team completely supports Bohr's idea that they quoted in Ref. [23]: "There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we can say about Nature."

In interesting theoretical work [25] interference and entanglement have recently been studied in the frame of a so-called intrinsic approach. As a rule classical states are prescribed to the phase space, while quantum states, which are considered as linear functions on the dynamical variables, assign to the vector space formalism (the Hilbert space). Density matrices belong to bilinears in the vectors. The authors [25] propose a generalized method of restoring an entangled pure state (a purification of the linear vector) from mixed states of the subsystems involved in entanglement. The pure density matrix is then treated as a measure of entanglement for the quantum system in question. In orthodox quantum mechanics linear operators, which act on the Hilbert space of states, are associated with observables. For instance, the Wigner distribution $f(\mathbf{x})$ is related to observables as well. Nevertheless, although $f(\mathbf{x})$ is defined in the Hilbert space [25] its arguments belong to the phase space (note in the general case the Wigner function is determined as $f(\mathbf{x}, \mathbf{p}, t)$). So the phase space and the Hilbert one appear as interconnected, though the Hilbert space describes strictly stationary states of the quantum system in question.

Stapp [26,27] analyzing both theoretical and experimental results, which touch questions like these: Is quantum theory local or nonlocal? and Is nonlocality is real?, has adduced many arguments for this or that point of views and specifically noted that quantum theory is still formulated as an indeterministic theory.

Among other urgent topics that have been developing we would like to mention research by Cramer [28], Griffiths [29], and Holland [30]. Cramer [28] considered an explicit and fully causal nonlocal mechanics for describing quantum events, which allowed him to claim about new insight into the reality behind the quantum mechanical formalism. The basic element of his theory is transaction describing a quantum event as an exchange of advanced and retarded waves. However, the author did not touch a nature of the waves, i.e. whether they are electromagnetic, inert, gravitational, or some other lineage. Moreover, he noted that the verification of the theory met grave difficulties.

Griffiths [29] introduces probabilities and stochastic processes as part of the foundations of quantum mechanics. He uses the mathematics of Hilbert space and constructs quantum principles known as consistent histories, or decoherent histories, that appears in his approach as basic principles of quantum theory.

Holland [30] adventures causal deterministic ideas by de Broglie and Bohm, though a surrounding quantum wave that guides a particle is treated in the framework of statistical mechanical type probabilities. For further reading on the Bohmian mechanics we would like to refer the reader to Goldstein [31]. Some other interpretations of quantum mechanics are stated in Refs. [32,33]; some aspects of the measurement problem and approaches to its solution are posed in Ref. [34].

Although quantum mechanics demonstrates a unique predictive success, it is still hampered by severe conceptual difficulties that scientists have tried to clarify. Looking for the answer to the question: What is quantum mechanics about?, researchers extend frames of the probabilistic basis of quantum theory. Nevertheless, quantum mechanics as such seems as a quite closed theory. Mermin [35] holds the same opinion: "First of all, by 'quantum mechanics' I mean quantum mechanics as it is – not some other theory in which the time evolution is modified by nonlinear or stochastic terms, nor even the old theory augmented with some new physical entities (like Bohmian particles) which supplement the conventional formalism without altering of its observable predictions. I have in mind ordinary everyday quantum mechanics." Muynck [36] shares this view as well: "Whether quantum mechanics just describes the 'phenomena', or whether it describes 'reality behind the phenomena'? In particular, within the quantum mechanics formalism I find no reason to conclude that experimental violation of the Bell inequality would imply any nonlocality (even though there is some nonlocality involved in the quantum mechanical formalism!). In my view the conceptual difficulties of quantum mechanics are mainly man-made, as a consequence of too high an expectation of the extent to which this theory describes 'reality behind the phenomena'."

Notwithstanding this, the inquisitive mind wishes to light upon a secret 'behind the phenomena.' In what way can it be done? It is obvious that we should extend quantum mechanics to the sub atomic area at which the initial notions quantum mechanics operates with will become clear. Among such notions we first of all should mention the following: de Broglie wavelength, Compton wavelength, wave-particle, ψ -function, spinor, operators of physical values, commutativity and noncommutativity of operators, Heisenberg's uncertainties, spin, Pauli exclusion principle, Lorentz noninvariance of the Schrödinger equation, discrepancy between Schrödinger's (nonrelativistic) and Dirac's (relativistic) formalisms and the absence of an intermediate formalism, Zitterbewegung, and so on.

If we are capable to make clear all of the basic notions of quantum theory, we in fact will clue the constitution of Nature at a deeper level. On the other hand, disclosing the notions above we shall automatically arrive at the complete determinism, that is, submicroscopic deterministic quantum the-

ory... Such a theory being constructed will unravel new peculiarities and links in quantum systems (including those that fall within electroweak and strong interactions).

2 Clarification of fundamental notions

2.1 Space

De Broglie [37] wrote about a subquantum medium that should be presented in works studying the problem of the causal interpretation of quantum mechanics. But what kind of a medium? Many of his ideas disclosed Lochak (see, e.g. Ref. [38]), the nearest collaborator of de Broglie and the President of Fondation Louis de Broglie (Paris, France). Nowadays we face a huge number of works dedicated to such kind of a medium that many researchers call an aether. Researchers who construct models of an aether note that conceptual difficulties of orthodox quantum theories rise just from denying an aether, because doing so we exclude the possibility of matter to interact with the aether. Some of these researchers see all particles as being conceived from a unique corpuscle (see, e.g. Ref. [39,40]) and, moreover, some direct experimental evidences of the interaction of matter with a subquantum medium is indeed demonstrated by Baurov [40].

What was the opinion of Einstein about an aether? In his well-known work "Aether and the theory of relativity" [41] he stated that since space was endowed with physical qualities, an aether existed. Then he mentioned that according to the general theory of relativity space without an aether is unthinkable: in space without an aether light would not propagate; there would not any space-time intervals in the physical sense, etc. However, in summary Einstein stressed that this aether might not be thought of as endowed with quality characteristic of ponderable medium, as consisting of parts that might be tracked through time.

Notwithstanding Einstein's determination that rejected the idea of likeness between an aether and a typical medium, quantum mechanics, which was constructed later, introduced a new understanding of space. In work "Is there an aether?" Dirac [42] considering relations between general relativity and quantum mechanics noted that although the relativity posed the objections to an aether, quantum mechanics practically removed them. Thus, a subquantum medium in fact might be intervened in the behavior of moving particles introducing a peculiar quantum mechanical strangeness.

However, researchers still did not set themselves the problem of constructing a detailed theory of quantum mechanics derived from the structure of space. Hitherto we have met only incomplete and uncoordinated models and concepts of space and quantum mechanics, which consider only separate aspects of the structure of space and the interaction of quantum systems with the space. In no circumstances such studies cannot be called rigorous theories of quantum

behavior of matter. It should be particularly emphasized that since the beginning of the 1950s de Broglie's major idea [36] was the construction of a double solution theory. The theory should satisfy the Schrödinger formalism and simultaneously introduce the deepest deterministic description of the behavior of a quantum system.

It seems that so far the author in fact has been along who tried to follow de Broglie's ideas as close as possible. The main starting point of the author's concept [43,44] was the inner construction of a subquantum medium. Why do we need a substrate? Because a specialist who works in the field of condensed matter physics cannot see particles that move and interact in an absolute emptiness, i.e. a vacuum. Note that in the case of condensed matter, particles move in a lattice of atoms/molecules. The lattice can be ordered or disordered, dense or not compact, but it always exists! Besides, experiments in high energy physics unambiguously demonstrate that particles can be created in any place of space and, moreover, high energy physics predicts a critical size, 10^{-30} m, at which all kinds of physical interactions should coincide. Furthermore, high energy physicists operate with the notion of an abstract superparticle whose different states are electron, positron, muon, quark (u -quark, d -quark, and the others), etc. Thus a fuller picture of the substrate was beginning to emerge: The primary substrate might be tightly composed of real superparticles, primary blocks, whose size is around 10^{-30} m.

Those first steps then passed into a rigorous mathematical theory of the real space developed by Bounias and me in a series of works [45-47]. Why do we prefer the notion of the space over that of an aether? The author tried to answer this interesting question in article [48]. The matter is that this is the pure historical issue: ancient Indian sages possessed an inexplicable deep knowledge regarding the constitution of the physical world and they used term 'space' ('loka' in Sanskrit) [49]; ancient Greeks partly borrowed their knowledge and transformed 'loka' into 'aether'. It is interesting that Newton also adhered the notion 'space' that was in his opinion constructed of compactly stacked small rigid balls.

In our works [45-47] studying the constitution of the real space (i.e., a 4-D space-time) we have used topology, set theory and fractal geometry. An abstract lattice of empty set cells \emptyset has been shown to be able to account for a primary substrate in a physical space. This lattice is a fractal lattice if it allowed for the magma $\emptyset^\emptyset = \{\emptyset, \mathbb{C}\}$ constructed with the empty hyperset and the axiom of availability. Spacetime is represented by ordered sequences of topologically closed Poincaré sections of this primary space. We have demonstrated that the antifounded properties of the empty set provide existence to a lattice involving a tessellation of the corresponding abstract space with empty balls. This structure has thus been called a *tessellattice*. M. Bounias introduced the 'Moment of Junction' that allowed us to investigate the composition of indicative functions of the position of points within the topological structures and to account for elements of the differential geometry of space-time.

The tessellattice represents a degenerate space-time, i.e. in this case all

cells (in other words, balls) are degenerated. A particled ball provides a formalism describing the elementary particles proposed in Refs. [43,44]. In this respect, mass is represented by a fractal reduction of volume of a ball, while just a reduction of volume as in degenerate cells, which was initially postulated in Refs. [43,44,50-52], is not sufficient to provide mass (because a dimensional increase is a necessary condition). Accordingly, if V_o is the volume of an absolutely free cell, then the reduction of volume resulting from a fractal concavity is the following: $V^{\text{part}} = V_o - V_f$. The mass m of a particled ball is a function of the fractal-related decrease of the volume of the ball:

$$m \propto (1/V^{\text{part}}) \cdot (e_v - 1)_{e_v > 1} \quad (2)$$

where (e) is the Bouligand exponent, and $(e - 1)$ the gain in dimensionality given by the fractal iteration.

The moment of junction allows the formalization of the topological characteristics of what is called ***motion*** in a physical universe. It is the motion that was called by de Broglie as the major characteristic determining physics. While an identity mapping denotes an absence of motion, that is a null interval of time, a nonempty moment of junction stands for the minimal of any time interval. Sidharth [53] argued that a minimum spacetime interval should exist and that "one cannot go to arbitrarily small spacetime intervals or points". In our sense, there is no such "point" at all: only instants that at bottom of fact do not reflect timely features.

In such a manner, a (physical) vacuum that is hazy something or nothing in all modern quantum theories should be replaced by the real space, or physical space stated above.

High energy physics working on sub microscopic scales proposes some Higgs condensate that would be initial at the creation of the physical world. Nonetheless, the Higgs condensate of models of grand unification of interactions is not constructed in a real 4D space-time and moreover, it does not give any idea in what way it can manifest itself in quantum mechanics. Inasmuch as quantum mechanics is the most reliable basis for all other quantum theories, any new quantum concept has to produce orthodox quantum mechanics as a limiting case of the theory constructed (i.e. de Broglie's thesis concerning the double theory solution should be satisfied). However, either quantum chromodynamics, or some other contemporary theory such as string theory and others are not able to mutate in the orthodox quantum mechanical formalism. Quantum field theories and their derivatives suffer from undetermined field variables (φ , φ^4 , etc.) constructed in abstract spaces, and so on. Group methods also isolate themselves from both the constitution of the space and the direct measurement.

General relativity does not deal with any substrate, its major subject is geometry. However, we should not forget that the relativity separates the mass from the geometry, i.e. matter from space. If we assume that matter appears from the space, which in turn is a substrate, we immediately arrive

at the conclusion that the matter should interact with such a space: the space itself becomes material.

Thus the submicroscopic theory of the real space constructed in Refs. [45-47] discloses very new horizons in physics. In the area of macroscopic physics this is the possibility of deriving the theory of gravity starting from quantum mechanics. Recently a definite success in this direction in fact has been achieved [50,54-56]. In the sub atomic area the reconsideration of the strong and electroweak interaction starting from deeper first principles is still waiting for pioneers.

2.2 Long-range action

Ehrenfest [57] pointed out that by conventional quantum mechanics, particles can interact simultaneously even if they are spaced at any quantity of kilometers; he even exclaimed: "What a strange theory we have!" Long-range action of quantum mechanics was also emphasized by Pauli [58]; in particular, he noted that quantum mechanics bears up against a hypothetical basis that the speed of the interaction in the quantum mechanical range $c = \infty$ and that the gravitational interaction is negligible, the constant of gravitational interaction $G = 0$.

For instance, let us turn to the problem of hydrogen atom, a typical example of long-range action in quantum mechanics, which also was stressed by Arunasalam [59]. The radial part of the Schrödinger equation written for a particle in a spherically symmetric electrostatic potential $V(r)$ has the form (see, e.g. Schiff [60])

$$-\frac{\hbar^2}{2m} \frac{d^2\chi}{dr^2} + \left[V(r) + \frac{l(l+1)\hbar^2}{2mr^2} \right] \chi = E\chi \quad (3)$$

where $\chi(r)$ is the radial wave function. The second term in the square brackets is stipulated by the potential energy associated with the moment of momentum of the particle. The potential energy

$$V(r) + \frac{l(l+1)\hbar^2}{2mr^2} \quad (4)$$

ensures the stability of the particle orbit. In the case of the hydrogen atom the potential $V(r) = e^2/(4\pi\epsilon_0 r)$ and the equation of related motion of an electron and proton has the form similar to Eq. (3).

However, it should be noted that the Schrödinger *quantum* equation (3) includes the potentials $V(r)$ written in pure *classical* terms, much as in the problem of Newton gravity where $V(r) = Gm/r$. In Eq. (2) $V(r)$ is a usual classical presentation of the motionless charge surrounded by the electric field. The mass m that enters *quantum* equation (4) is also a pure *classical* parameter. Hence even the most comprehensive quantum mechanical description of the quantum system studied is only a quasi-classical pattern.

Thus if one still wishes to remain devoted to orthodox quantum mechanics, the fundamentals will be kept in the shade of its statistical conformities.

On the other hand, since the tessellattice, or the real space is a lattice of densely packed balls [45-47], all the phenomena that can take place in the tessellated space a priori are deterministic. In fact we do not need any necessity to introduce long-range action because all kinds of interactions will now be occur through superparticles, building blocks of the space. This means that any actual microscopic theory should be specified by short-range action, i.e. it should be characterized by carriers, elementary excitations, or quasi-particles of the tessellated space. In our theory such excitations were called 'inertons' [43]. It seems this appellation is best matched to their physical nature because 'inertia' means a resistance to the motion. In fact any particle moving in the tessellattice should undergoes collisions on the side of coming cells, superparticles. Such an interaction results in the creation of the tessellattice's excitations, inertons, which therefore for ever become attached to particles. Moreover, in paper [56] it was directly shown that a particle's inertons carry the proper inert mass of the particle, $m_0/\sqrt{1 - v_0^2/c^2}$. The value of mass of an inerton can vary approximately from 10^{-85} to 10^{-45} kg [57].

2.3 Wave-particle

Classical mechanics is constructed in the real space (i.e. in a 3D space or 4D space-time) where particles – material points – are endowed with such measurable characteristics as the position, velocity, momentum, and kinetic energy. A classical wave is specified by measurable properties as well, namely, the wavelength and frequency. In higher energy physics particles do not demonstrate wave properties as well; they seem material points. Thus, wave properties of particles, which appear at low and intermediate energies, can indeed be associated with an intervention of a subquantum medium, i.e. space, that imposes the wave behavior on moving particles.

In 1924 de Broglie (see, e.g. Ref. [61]) formulating the Jakobi theorem in the real space derived the de Maupertuis principle: A real trajectory of a particle that moves from point A to point B of the space is characterized by the minimum action

$$S = Et - mv(\alpha x + \beta y + \sqrt{1 - \alpha^2 - \beta^2} z) \quad (5)$$

where E is the kinetic energy of a particle, m its mass, v its velocity, t is time, and α and β are direction cosines.

Then de Broglie derived the solution to the wave equation that described a monochromatic wave spreading in an isotropic medium. This allowed him to write the phase of the wave in the form

$$\varphi = \nu t - \frac{1}{\lambda}(\alpha x + \beta y + \sqrt{1 - \alpha^2 - \beta^2} z) \quad (6)$$

where ν is the frequency of the wave and λ its wavelength. φ is the total integral of the equation of geometric optics, which takes account of the Fermat

principle: A real ray spreading from point A to point B is characterized by the minimum phase.

Setting $\nu = E/h$ and then comparing expressions (5) and (6) de Broglie came to his famous relationships for a canonical particle

$$E = h\nu \quad \text{and} \quad \lambda = h/mv, \quad (7)$$

In expressions (7) parameters E and mv (the energy and the momentum, respectively) belonged to the particle, but the frequency ν and the wavelength λ were characteristics of a wave that should accompany and guide the particle at its motion in the real space.

Note that the relationships (7) enable one readily to derive the Schrödinger equation [61]. So, de Broglie's transparent idea that a moving particle is accompanied by an actual wave did not receive any further development.

The Schrödinger and Dirac formalisms say nothing about true trajectories of the quantum system studied that is a direct consequence of the probabilistic approach to the description of quantum phenomena. Of course, one could use Feynman diagrams for any entity, with their point-like particles and photons, all having some absolute position and momentum. However, we cannot get the true path. Instead we must draw infinitely many Feynman diagrams and then calculate Feynman's path integrals, which make it possible to find out only the most verisimilar trajectory of the quantum system.

Once again, the inner reason is that conventional quantum mechanics is developed in the phase space, but not in the real one. Indeed, can one clarify the duality of a "wave-particle" in the real space where only a particle and a wave can separately be determined? The same is noted by Ligare and Oliverly [62]: "It is not always clear which aspects of classical wave behavior are related in a fully quantum-mechanical treatment, or where to draw the line between wave-like aspects and particle-like aspects and how to justify the division".

Since in the author's approach the real space is the tessellattice formed by densely packed superparticles, a mechanics of a particle should be different from that typical for classical mechanics. The mechanics constructed in the tessellattice must take into account the interaction of a moving particle with the surrounding lattice. A detailed theory of the motion of a particle interacted with superparticles of the tessellated space was constructed in Refs. [43,44,50]. It has been argued that a deformation coat, or a crystallite, is formed around a created particle, which is identical with the deformation coat that is formed around a foreign particle in the crystal lattice. The size of the crystallite is associated with the Compton wavelength of the particle, $\lambda_{\text{Com}} = h/mc$ and the role of the crystallite is to shield the particle from the degenerate space. The mechanics constructed is exemplified by elementary excitations of the surrounding space, i.e. inertons, which accompany the moving particle. The Lagrangian of a moving particle has the form (simplified here)

$$L = \frac{1}{2} g_{ij} \dot{X}^i \dot{X}^j + \frac{1}{2} \sum_{l=1}^N \tilde{g}_{ij}^{(l)} \dot{x}_{(l)}^i \dot{x}_{(l)}^j - \sum_{l=1}^N \frac{\pi}{T_l} \delta_{ij} [X^i \dot{x}_{(l)}^j + v x_{(l)}^j]. \quad (8)$$

Here the first term describes the kinetic energy of the particle, the second term depicts the motion of the ensemble of N inertons and the third term characterizes the interaction between the particle and the ensemble.

In the so-called relativistic case, when the particle's velocity v approaches to the velocity of light c , the Lagrangian is chosen in the classical form

$$L = -m_0c^2\sqrt{1 - v^2/c^2} \quad (9)$$

in which, however, the following transformation is made

$$v \longrightarrow [g_{ij}\dot{X}^i\dot{X}^j + f(X, x, v, \dot{x})]/g \quad (10)$$

where the function f includes terms analogous to the second and third terms of expression (8).

Equations of motion of the particle and its inertons have been studied in detail. It has been shown that the motion in fact is marked by de Broglie relationships (7). Moreover, the inner meaning of all the parameters has been clarified. In particular, the particle's de Broglie wavelength represents the amplitude of spatial oscillations of the particle. The particle emits inertons running odd sections $\lambda/2$ of its path and its velocity gradually decreases from v to 0. During even sections $\lambda/2$ the particle re-absorbs inertons again and its velocity is restored to the value of v . The frequency $\nu = 1/2T$ where T is the period of collisions of the particle with the center-of-mass of its inerton cloud.

The particle's inerton cloud oscillates around the particle with the same frequency ν and the cloud's amplitude Λ satisfies expression

$$\Lambda \simeq \lambda c/v \quad (11)$$

where c is the velocity of inertons, which is of the order or over the velocity of light. The theory constructed in some aspects is similar to the kinetic theory of a system of two linked objects that are characterized by free path lengths λ and Λ .

The availability of the oscillating inerton cloud that accompanies a moving particle automatically means that the particle indeed goes with a peculiar real wave. Since the particle is always found in the center of the system 'particle-inerton cloud', the system as a whole may be treated as a wave travelling along a given direction. The range of the space covered by the particle's inerton cloud determines an area of employing of the wave ψ -function formalism. So the double solution theory approach allows us to fill the pure probabilistic interpretation of the Schrödinger wave ψ -function with the concrete physical contents described above. The problem of the measurement of an abstract wave ψ -function when it collapses to a measurable actual point now can easy be account for the re-absorption of inertons by their particle.

2.4 Matter waves

Although in quantum mechanics the behavior of particles are described by pure formal statistical formalism, canonical particles, nevertheless, demonstrate properties of real waves, i.e. the matter waves, which received empirical

confirmation in the diffraction experiments. Therefore, particles in fact possess real wave properties predicted by de Broglie, which automatically implies that the pure probabilistic interpretation of the ψ -function is not complete.

Briner et al. [63] published an experimental work entitled "Looking at Electronic Wave Functions on Metal Surfaces", in which they demonstrated the colored spherical and elliptical figures, which the authors called "the images of ψ wave functions of electrons". Virtually they gave the evidence that the electron is not a point-like object, though the high energy physics asserts that it is a point object with the size no larger than 10^{-18} m. Thus they fixed an actual perturbation of the space around an electron in the metal! The authors subconsciously rose against the probabilistic interpretation of the ψ wave accepted by the Copenhagen School concept and, moreover, they practically proved the fallaciousness of the statement of the concept. Consequently, the experimental data point to the fact that the wave ψ -function is not abstract but measurable matter.

Evidently, inertons as a substructure of the matter waves have already received an implicit support among researchers [63]. We shall discuss other manifestations of inertons in Section 3.

2.5 Lorentz invariance

All correct theories should be Lorentz invariant, i.e. they and Einstein's special relativity should agree (see, e.g. Ref. [64]). Nevertheless, the Schrödinger equation is not Lorentz invariant but it perfectly describes quantum phenomena and we trust wholly the results derived from the equation. How is it possible?

It seems that the disagreement between the strong theoretical conclusion and the experimental veracity is hidden in the statistical approach to the Schrödinger formalism. In papers [43,44] the Schrödinger equation was derived from deeper first principles that in fact removed a very unpleasant conflict that so far took place between nonrelativistic quantum mechanics and special relativity: Unlike the traditional presentation, the Schrödinger equation gained in paper [44] is Lorentz invariant owing to the invariant time entered the equation. Besides, it has been shown in Refs. [44,56] that the tessellated space contracts a moving object and its cloud of inertons in accord to the formalism of special relativity (see also Ref. [46]), i.e. by the factor of $\sqrt{1 - v^2/c^2}$.

2.6 Unification of Schrödinger and Dirac formalisms

Why Schrödinger's and Dirac's approaches are so dissimilar? Why is an intermediate approach lacking? It seems that this issue has never been raised by researchers so far at all. Nevertheless the problem is very serious and it must be resolved.

In orthodox quantum mechanics there is no singled valued parameters E and ν in the expression $E = h\nu$ applied to a moving canonical particle. In

one case $E = \frac{1}{2}m_0v^2$ (see, e.g. Schiff [60], p. 33), and in the other one $E = m_0c^2/\sqrt{1 - v^2/c^2}$ (see, e.g. Schiff [60], p. 364). Which is true?

The problem has been studied by the author in paper [50]. To answer the question let us consider the three relationships below, namely: de Broglie's $\lambda = h/mv$, Compton's $\lambda_{\text{Com}} = h/mc$, and $\Lambda \simeq \lambda c/v$ (11). This allows relation (11) to rewrite as follows

$$\Lambda \simeq \lambda_{\text{Com}} \frac{c^2}{v^2}. \quad (12)$$

It has been shown in Refs. [44,50] that a moving particle periodically passes its kinetic energy $\frac{1}{2}m_0v^2/\sqrt{1 - v^2/c^2}$ on to the particle's inerton cloud. That is why, as follows from relation (12) when the velocity v of a particle satisfies the inequality $v \ll c$, the inerton cloud that guides the particle carries the particle's kinetic energy $E = \frac{1}{2}m_0v^2$. It is the energy that is measured by the tool. At a distance about Λ from the particle its inerton cloud undergoes obstacles and passes the corresponding information to the particle. This is the typical de Broglie's "motion by guidance" and the utilization of the Schrödinger formalism is quite correct in this situation.

When $v \rightarrow c$, the inerton cloud becomes virtually closed inside of the particle's crystallite whose size is determined by the Compton wavelength λ_{Com} . The total energy of the crystallite coincides with the total energy of the particle, $E = m_0c^2/\sqrt{1 - v^2/c^2}$, and if so the tool will measure this energy. In such a manner when $v \rightarrow c$ the energy of the particle at rest m_0c^2 explicitly reveals itself at the measurement and, therefore, in this approximation the Schrödinger formalism fails and the Dirac formalism becomes effective.

2.7 Spin

What is spin? It is one more mystery of the microworld. In quantum mechanics spin is perceived to be a certain inner property of canonical particles. Quantum field theories define spin as an "inseparable and invariable property of a particle" (see e.g. Ref. [64], p. 17). That is all.

As a rule the notion of spin of a particle is associated with an intrinsic particle motion. Several tens of works have been devoted to the spin problem. Major of them is reviewed in recent author's papers [50,52]. Main ideas of the works quoted there were reduced to a moving particle that was surrounded by a wave, or a small massless particle, or an ensemble of small massless particles, which engaged in a circular motion.

Of course, it seems quite reasonable to assume that spin reflects some kind of proper rotation of the particle. However, canonical particles possess also electrodynamic properties and the operation *rotor* is the principal characteristic of the particle's electromagnetic field. Since quantum electrodynamics and quantum mechanics of a particle must be in accord, the idea of rotation regarding the notion of the particle's spin should be abandoned.

In the author's concept particles are determined as spatial objects in the real space, which in fact makes it possible to investigate the notion of spin in

detail. In this case along with an oscillating rectilinear motion, the particle may undergo also some kind of an inner pulsation, like a drop. Two possible pulsations of a particle either along its velocity vector or diametrically opposite to it have been associated with the two possible projections of the particle spin, i.e., the two own pulsations of the particle in the real space are exhibited by two so-called spin-1/2 projections, $\pm\hbar/2$, in the phase space [50]. Any spin bigger 1/2 is the property of a composite quantum system.

The Pauli principle makes allowance for the spin "polarization" of inerton clouds of two interacting particles. If inertons of the two particle transfer the same projection of spin determined above, the interaction will be repulsive; if spins of the particles are opposite, the interaction will be attractive.

2.8 Heisenberg's uncertainties

Although there are Heisenberg's uncertainties for the coordinate and momentum and the energy and time of a particle,

$$\Delta x \Delta p \geq \hbar, \quad \Delta E \Delta t \geq \hbar, \quad (13)$$

we are not able to write any similar relation for the particle mass, which should also be fuzzy in a undetermined volume, the same as the particle itself (the mass must follow the particle!), as the probabilistic formalism prescribes.

De Broglie [65,66] studied the problem of the mass behavior and came to the conclusion that the dynamics of particles had the characteristics of the dynamics of the particles with a variable proper mass. He was the first to indicate that the corpuscle dynamics was the basis for the wave mechanics. With the variational principle, he obtained and studied the equations of motion of a massive point reasoning from the typical Lagrangian

$$L = -M_0 c^2 \sqrt{1 - v^2/c^2} \quad (14)$$

in which the velocity v of the point and the velocity of light c were constant along a path. De Broglie's pioneer research allows one to suggest that a real wave, which indeed has to accompany the moving particle, must complement the deficient value of the momentum and the energy of the particle. Then, say, we know the momentum and the energy, but have uncertainties in coordinate and time. If we assume the existence of an actual wave that travels in the space together with the particle, we can readily propose that the particle is entrained by the given wave and, therefore, position and time of the particle become in fact undetermined in a concrete point as they become functions of the travelling wave.

The uncertainty principle is a direct consequence of the probabilistic approach to quantum phenomena when only one of two subsystems is taken into account, namely, we treat the behavior only a particle, but totally ignore its inerton cloud that accompanies the particle.

It seems that in some situations the uncertainties are sound not universally true. For instance, Gong [67] has recently re-analyzed two well-known ideal

experiments: (i) Heisenberg's γ -ray microscope experiment and (ii) the single slit diffraction experiment. He has shown that in the case (i) the uncertainty principle cannot be employed for a quantum system if its size is equal or large than the resolving limit Δx_{mic} of the microscope. In the situation (ii) if a particle has a certain position in the slit, the uncertain quantity of the position is also wanting. Hence in both cases the relation $\Delta x \Delta p \sim 0$ is held, which is incompatible with the prediction (13).

A conclusion can be drawn that the uncertainty principle is not universal. It should be applied with a great caution. The reason is that the nonlinear behavior of a quantum system would stem from a subtle interaction with the environment, which is discussed below.

3 Field generated by motion

3.1 Experimental evidence

Classical mechanics itself has evidence that the space should be treated as a substrate, though such direct demonstrations as inert forces and the centrifugal force are not yet taken into account in quantum and gravitational physics.

At the same time quantum theories that describe electrodynamics, weak and strong interactions are characterized by their own carriers, quasi-particles or particles: photons, W^\pm - and Z^0 -bosons, and gluons, respectively. In this paper we have argued that quantum mechanics being constructed in the real space immediately gives rise to its proper carriers, namely, inertons. We have already talked about experimental evidence presented by Baurov [40] and Briner et al. [63]. Here we would like to inform about other recent data. Benford [68] could record radiation of a unknown nature from a ferrite disk revolving on its axis. Urutskoev and co-workers [69] registered a new "strange" radiation as well when they studied transmutation of chemical elements in foils during electric discharge – the effect that is still considered as completely impossible among the majority of nuclear physicists.

The experimental verification of submicroscopic quantum mechanics, namely, that moving objects are accompanied by inertons, elementary excitations of the space, has been carried out in papers [54,70,71]. In work [54] we started from a hypothesis that in condensed media inerton clouds of separate entities should overlap forming the entire inerton field that should be quantized the same as the phonon field. In a solid, the force matrix W determines branches of the solid's acoustic vibrations. We supposed that the force matrix should include in addition to the phonon term also the term associated with the overlapping of inerton clouds; so, the force matrix transformed to $W = W_{\text{acust}} + W_{\text{inert}}$. Therefore an outside inerton field would be able to influence the solid in the same way as the acoustic field does. Since the Earth is a power source of the inerton radiation. We in fact could fix changes in the fine morphological structure of samples studied, Figure 1 (experimental details

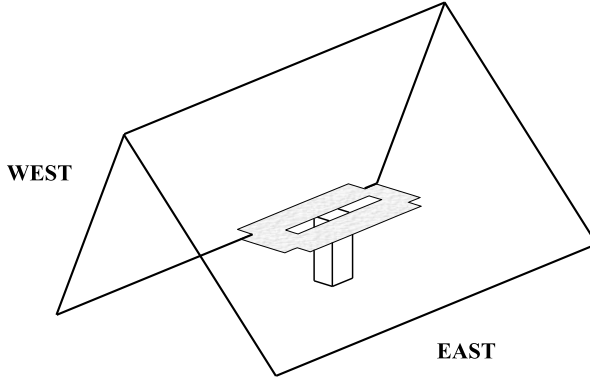


Figure 1: Resonator of the Earth inerton field made of two transparent organic glass plates and the sample (a razor blade) whose fine morphologic structure changed under the Earth inerton radiation, which was fixed by the electron microscope [54] (for further reading about the phenomenon see Ref. [73].)

see in Ref. [54]). The device that measures the inerton radiation has recently been constructed by my colleagues, Figure 2.

In paper [70] the anomalous photoelectric effect occurring under strong irradiation was examined from the submicroscopic standpoint. The phenomenon, in essence, is this: these are electrons' inerton clouds which absorb photons of an incident laser beam, because the cross-section of an electron's inerton cloud σ_{cloud} much exceeds that of an atom $\sigma_{\text{atom}} \sim 10^{-2} \text{ nm}^2$ (the actual electron's cross-section satisfies inequalities $\lambda^2 < \sigma_{\text{cloud}} < \Lambda^2$). It has been shown that the multiphoton theory that is still employed by the majority of specialists in quantum optics since the mid-1960s is wrong as the photoelectric effect studied has a linear dependence on the intensity of light, though the multiphoton theory is strongly nonlinear theory; this also has long been stressed by Panarella [71]. The result [70] is supported by comparison with a great numbers of experimental data.

In paper [72] it is shown that in the $\text{KIO}_3 \cdot \text{HIO}_3$ crystal hydrogen atoms co-operate in peculiar clusters in which, however, the hydrogen atoms do not move from their equilibrium positions, but become to vibrate synchronously. The interaction between the hydrogen atoms is associated with the overlapping of their inertons. The exchange by inertons results in the oscillation of mass of hydrogen atoms, which manifested itself in the IR spectra analysed.

3.2 Prospects for quantum physics

Since photons and inertons are two major quasi-particles, which are excited in the tessellated space [74], we would build up a submicroscopic theory of the diffraction phenomenon both for particles and photons, which today is still limited by the geometrical optics approximation. The theory will also elucidate a microscopic origin of the phenomenon of dispersion of light and,



Figure 2: Device "URGA-1" (the Universal Registrar of Geological Anomalies) that measures the inerton radiation, in particular, in pyramid-like constructions with an effective size over 1 m.

moreover, it will show that just inertons – carriers of the matter waves – play the fundamental role in the diffraction/dispersion phenomenon.

The said is not a fantasy by the author. A submicroscopic theory of the phenomenon of the diffraction of photons/particles promises new interesting results that would be very considerable for applied physics. Indeed, a mechanism of the diffractionless of single photons revealed by Panarella (see, e.g. his review article [75]) about 20 years ago remains completely unclear. The behavior of photons was typical for that of classical corpuscles: single photons passed through a pinhole and did not form any fringe on the target. This would mean that the diffraction pattern is formed only due to the interaction of each travelling photon with the surrounding clouds of inertons, which ceaseless oscillate around their entities. The diffractionless would mean a peculiar photon channelling when a travelling photon is not scattered by surrounding inerton clouds of the matter. At what conditions is it possible? The answer will shed light on other quantum phenomena such as entanglement, teleportation, etc. Thus the inerton field is capable to play a role of the control field that will replace an indeterministic 'randomness of the quantum world'.

Nakhmanson [16] notes that the idea of informational experiments with particles has never been publicly discussed. Then he continues that if particles have consciousness, they may receive a signal and then will transfer it to matter. Submicroscopic quantum mechanics constructed in the real space completely supports this idea, because the particle's inerton cloud plays the role of a peculiar 'consciousness' of the particle, which was hypothesized in Ref. [16].

As the control field, a flow of inertons would provide for controlled low energy nuclear reactions like those that were revealed by Benford [68] and Urutskoev et al. [69], though in their experiments they only claimed about a new "strange" radiation. In the recent research conducted by our team we have obtained much more remarkable results in this area as long as we followed the submicroscopic theory stated above.

4 Concluding remarks

Thus, if we turn from the statistical standpoint on the nature of everything, we arrive at the very new pattern of the physical world described above. New peculiarities and links come to light. From the viewpoint of submicroscopic determinism many urgent problems of contemporary physics abruptly lose their supreme meaning, because these problems appear now as typical phenomenological issues whose decision is found at a deeper level of our knowledge.

For instance, Arunasalam [59] has recently discussed the views on the fundamental problems expressed by different sets of famous physicists (Einstein, Dirac, Feynman, Pauli, Bethe and others) and shown that the views are in sharp contrast: covariance versus invariance, relativistic versus nonrelativistic electron theories, etc. The problems indeed are considerably important. However, if we are resting on deeper, i.e. deterministic first principles, such problems as charge conjugation **C** and **CPT** violation seem not determined owing to vagueness of the notions *charge*, *space*, and *time* in the framework of the theory that tries to resolve the problems.

From the viewpoint of the theory of space constructed in works [45-47] and submicroscopic quantum mechanics discussed above modern theories on particle physics do not show up as fundamental. In the future, without doubt, they will be re-analysed on the basis of the submicroscopic concept. Similar problems remain to face gravitational physics. For example, the problem of gravitational waves seems very farfetched. Gravitational waves are not a realistic solution to the Einstein equations, as has been shown by Loinger [76], and they are forbidden by submicroscopic quantum mechanics developed in the real space [54].

Consequently, further sophisticated study of the constitution of the real space and the deriving matter and physics laws from the space are the shortest road to the progress of science and the advanced technology.

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