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AN UNITARY QUANTUM FIELD THEORY

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Abstract : The paper proposes a model of a unitary quantum field theory where the particle is represented as a wave packet. The frequency dispersion equation is chosen so that the packet periodically appears and disappears without changing its form. The envelope of the process is identified with a conventional wave function. Equations of such a field are nonlinear and relativistically invariant. With proper adjustments they reduce to Dirac, Schrödinger and Hamilton-Jacobi equations. A number of new experimental effects are predicted both for high and low energies.

Résumé : Cet article propose un modèle de théorie quantique des champs unitaire, où la particule est représentée par un paquet d'ondes. L'équation de dispersion de la fréquence est choisie de sorte que le paquet apparaît et disparaît périodiquement sans changer de forme. L'enveloppe de ce processus est identifiée à une fonction d'onde conventionnelle. Les équations d'un tel champ sont non linéaires et invariantes relativistes. Leurs limites appropriées se réduisent aux équations de Dirac, de Schrödinger et de Hamilton-Jacobi. Un certain nombre de nouveaux effets expérimentaux sont ainsi prédits aussi bien dans le do-

maine des hautes que des basses énergies.

Introduction

A theory which explains everything in terms of field seems likely to be the most direct way to obtain a relativistic description of quantum mechanical systems and to remove the existing inconsistencies. In that theory the observables are the quantities characterizing the field in different points of space-time. One has the impression that since the advent of the quantum theory no essential progress has been made in understanding it. This impression is strengthened by the fact that neither the quantum field theory nor the yet imperfect theory of elementary particles have introduced any essential changes either in the formulation or the solution of the following traditional questions ([1-5]) : What are the causes of the probabilistic interpretation of wave function and how may this interpretation be obtained from the mathematical formalism of the theory ? What actually happens to the particle when we "look at" it in any interference experiments ? The latter cannot be explained without using the concept of "splitting" a particle. "Exorcism" with the complementarity principle is of no help because this philosophy is invented ad hoc. Many experts believe that the foundation of theoretical physics of the future will be some unified field theory, a so-called unitary program. In such a theory particles are represented as field clusters, or wave packets. Mass is of pure field origin and the equations of motion and all interactions must result directly from field equations.

This paper treats an extremely simple but previously unexplored possibility of formulating a unitary quantum theory for a single particle in more detail than in ([1]). We shall discuss only most general properties shared by all particles.

1. The Movement of the Wave Packet in Medium with Dispersion

Since the physical reality should be described in terms of continuous field neither the concept of particles as invariable material points nor the concept of their motion can be of any fundamental importance. Only a restricted region of space in which the intensity of the field and/or the density of energy is especially high, may be considered a particle.

Imagine the following experiment. There is some hypothetical observer being at rest in some inertial system and located at point O of empty space free from other fields. A particle moves relative to this observer with a constant velocity $v \ll c$. Let us introduce a Cartesian system OXYZ so as the origin would be

at the point O and the X-axis would be parallel to the vector of the particle's velocity. Let us suppose that the particle is a wave packet of some yet unknown field. With the help of a hypothetical microprobe the observer measures the field of the moving particle as a function of time. It is presumed that the microprobe is many times smaller than the particle and this hypothetical measuring device neither consumes energy nor influences the field inside the particle. Obviously, an experiment of this kind is a Genankenexperiment and in principle it cannot be realized, but this does not prevent us to regard our imaginary device as the simplest possible. In other words, we are interested in the behaviour of the particle when "nobody is looking at" it. Let the result of the measurement be expressed by the function f(t) describing the structure of the wave packet the size of which is very small compared with de Broglie wave λ_B. Knowing v, velocity of the particle and the structure function f(t) the observer at rest can calculate "the apparent size" of the particle.

Let us suppose that inside the wave packet f(t) the linearity of the field laws is not violated and that the packet itself satisfies Dirichlet's conditions and may be expanded into harmonic constituents $A(\omega)$ called partial waves :

$$A(\omega) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} f(t') \, e^{i\omega t'} \, dt' \qquad (1)$$

In order to find the dispersion equation for partial waves we write down the Rayleigh relation for group velocity v of the wave packet :

$$v = v_p + k \frac{\partial v_p}{\partial k} = v_p + k \Big/ \left(\frac{dk}{dv_p}\right) \qquad (2)$$

Considering the wave number k of the partial wave as the function of the phase velocity v_p and integrating this relation, we obtain :

$$k = \frac{C}{v - v_p} \qquad (3)$$

where C is an integration constant. The integration was carried out under the condition that v is a constant and does not depend on the frequency of partial waves. The last fact follows immediately from the suggestion made earlier, as well as from the experimental law of inertia. Indeed, if we accept the particle to be a wave packet, then its group velocity should be equal to the velocity of particle's classical motion. Because in the absence of external fields the particle moves with constant velocity (the law of inertia) the group velocity of the packet is a constant quantity independent on the phase velocity of harmonic components.

The unsuccessful form of the dispersion equation (3) masks its main merit : the linear dispersion law which may be extracted from eq. (3) with the aid of substitution $v_p = \frac{\omega}{k}$

$$\omega = v\,k - C \qquad (4)$$

In this equation the integration constant C is unknown and will be determined later.

The harmonic components of the wave packet propagate in linear "medium" independently of one another. If the amplitude of partial wave is equal to $A(\omega)$, then at the moment of time t at the distance X from the observer the "height" of the wave at the point (X, 0, 0) is equal to

$$A = A(\omega)\; e^{-i(\omega t - k X) + i\phi} \qquad (5)$$

Because the wave's phase may be determined within an additive constant, it is necessary to introduce additional summand ϕ equal for all partial waves. It proves out however, that by means of simple translation of the origin of the coordinate system it is always possible to exclude the constant ϕ from further consideration.

The wave packet is a superposition of harmonic components (eq. 5), and by summing them we shall be able to analyze the spatial behavior of the packet :

$$\Phi(X, t) = \mathrm{Re} \int_{-\infty}^{+\infty} A(\omega)\; e^{-i(\omega t - k X)}\, d\omega \qquad (6)$$

Considering the wave number as a function of frequency $k(\omega)$, substitute the equations (1) and (4) into eq. (6) ; then after integration we obtain :

$$\Phi(X, t) = \frac{1}{2\pi}\,\mathrm{Re} \iint_{-\infty}^{+\infty} f(t')\; e^{-i\omega(t - t' - \frac{X}{v})}\, e^{i\frac{Cx}{v}}\, d\omega\, dt' = \mathrm{Re}\; e^{i\frac{CX}{v}}\, f(t - \frac{X}{v}) \qquad (7)$$

Analyzing the equation (7) one may see that the wave packet $f(X - vt)$ during its motion in the "medium" with linear dispersion law given by eq. (4) will at first disappear, but after half a wave length $\frac{1}{2}\lambda = \frac{\pi v}{C}$ it will reappear again, restoring its initial form and amplitude and only changing its sign ; after that the packet will again disappear in order to appear later and so on. At points with coordinates $X = \frac{\lambda}{2} n + \frac{\lambda}{4}$; (n = 0, 1, 2, 3, ...) the packet will disappear, whereas at points $X = \frac{\lambda}{2} n$ it will take up the previous initial form and amplitude (except possibly for a sign). Thus, the arbitrary packet $f(t)$ moving in the medium with linear dispersion may be considered as the running packet $f(X - vt)$ which is "inscribed" in the plane monochromatic envelope $\cos \frac{CX}{v}$. In order to find the integration constant C let us assume the equality of two wave lengths, namely for the envelope $\lambda = \frac{2\pi v}{C}$ and for de Broglie wave λ_B :

$$\lambda_B = \frac{2\pi}{k_B} = \frac{2\pi v}{C} \qquad (8)$$

Then $C = vK_B$ and the equation (7) becomes

$$\Phi(X, t) = \mathrm{Re}\; e^{iK_B X}\, f(X - vt) \qquad (9)$$

The earlier mentioned constant ϕ (the phase of partial waves is determined except for this constant) could enter the exponent of equation (9) as an additional summand and there fore could be simply excluded from consideration.

Any wave packet is constructed by means of superposition of sinusoidal waves which possess different frequencies, wavelengths and directions of propagation but nevertheless is confined to change continuously in some interval. Because the particle is a spatially extended object so the wave packet must possess finite dimensions. Any dispersion without dissipation leaves the energy spectrum unchanged, altering only the phase relations between the constituents of the spectrum. So the wave packet generally speaking, does not maintain constant its dimensions and form and smears out in space.

For the case of the linear harmonic oscillator Schrödinger [6] succeeded in constructing from the de Broglie waves a packet having a gaussian form, which was stable and didn't smear out in the course of time. However, Darwin(7) and Heisenberg(8) showed that the oscillator is in this respect a notice-able exception and in general the packets constructed from the de Broglie waves smear out in space.

Taking into account the fact of stable existence of particles their corresponding wave packets are to be constructed so as to prevent their smearing. This idea can be successfully realized for the wave group with linear dispersion law eq. (4). In this case the wave packet as it follows from eq. (7), does not change it's form in the course of time, but only periodically appears and disappears. The de Broglie wave is an envelope of this process and does not enter into the set of waves representing the packet. Owing to this statement one may take the dimensions of the packet much smaller than the de Broglie wavelength.

All the ideas stated above are the consequences from two postulates :

Postulate 1 : The particle is represented by a wave packet and is governed by linear field laws.

From the inertia law follows the linear dispersion law ; then the particle is proved to be represented by a running wave packet which is "inscribed" in a plane sinusoidal envelope.

Postulate 2 : The wavelength of the envelope is equal to the de Broglie wavelength.

2. Unitary Quantum Mechanics

The wave function $\Phi = e^{iK_B X} f(X - vt)$ of a single particle was obtained in the assumption of low velocities $v \ll C$. For its relativistic extension the wave function phase must be made relativistically invariant, or

$$\Phi = e^{-i(Et - \vec{p}\,\vec{X})}\, f(\vec{X} - \vec{v}t) \tag{10}$$

where $E = \frac{m}{\gamma}$; $\vec{p} = \frac{m\vec{v}}{\gamma}$ and $\gamma = \sqrt{1 - v^2}$ (in this Section units $c = \hbar = 1$ are used). As far as the structure function $f(\vec{X} - \vec{v}t)$ is concerned, it could be required that Φ would be scalar and satisfy the Klein-Gordon equation. Then we would have obtained the following expression for f

$$(v_i\, v_k - \delta_{ik})\, \frac{\partial^2 f}{\partial \xi_i\, \partial \xi_k} = 0$$

where $\xi_i = X_i - v_i t$; i,k = 1, 2, 3 and summation over equal indices. The two-component solution of the Klein-Gordon equation would have been then of the form :

$$\Phi = e^{-i(Et - \vec{p}\vec{X})} \begin{pmatrix} \frac{\gamma-1}{2\gamma}\, f - \frac{i}{2m}\, \vec{v}\, \frac{\partial f}{\partial \vec{\xi}} \\ \frac{\gamma+1}{2\gamma}\, f + \frac{i}{2m}\, \vec{v}\, \frac{\partial f}{\partial \vec{\xi}} \end{pmatrix} \tag{11}$$

In a similar way we would have obtained from the Schrödinger equation the Laplace equation for the structure function $\nabla_\xi^2 f = 0$ and the particle would have been represented as a spherical wave packet "cut up" by zeros of a spherical harmonic. But this approach can be used only for illustration, as a rough approximation with assumed linearity of field laws. Let us proceed in a different way. The simplest possible first and second order equations satisfied by the one-component relativistic wave function with an arbitrary structure function are of explicitly relativistic form

$$\left(U_\mu \frac{\partial}{\partial X_\mu} + im\right)\Phi = 0 \tag{12}$$

$$\left(U_\mu\, U_\nu \frac{\partial^2}{\partial X_\mu\, \partial X_\nu} + m^2\right)\Phi = 0 \tag{13}$$

where $U_\mu = \left(\frac{\vec{v}}{\gamma} ; \frac{i}{\gamma}\right)$ 4-velocity of particle, $X_\mu = (\vec{X}, it)$ and $\mu, \nu = 1, 2, 3, 4$. It would be natural to suppose that a particle of mass m, having an arbitrary spin is described by the relativistic equation

$$\left(\Lambda_\mu \frac{\partial}{\partial X_\mu} + m\right)\Phi = 0 \tag{14}$$

where Φ is an n-component column and Λ_μ are four square n-row matrices which describe the spin properties of a particle. These matrices depend on the particle velocity and satisfy the commutation relations which in turn depend on the spin values.

Let us express the particle energy (mass) in terms of field. For Dirac-like equations the nature of the charge at integer spin and energy at half-integer spin are indefinite. Furthermore, in relativistic electrodynamics according to the Laue theorem the components of the energy-momentum tensor of the electromagnetic charge-created field do not form 4-vectors and so there is just one way to express particle energy in the non-relativistic limit

$$E = \int \Phi^+ \Phi \, d^3 X \qquad (15)$$

The usual requirement in such cases is that the integral (15) should contain a Green function. But if the principles of developed unitary theory are literally followed the particle energy must be determined in the non-relativistic limit, as in eq. (15). Replace $\int \Phi^+ \Phi \, d^3 X$ by a relativistic invariant expression $<\Phi|\Phi>$ which, for instance, for a spinor field with a non-zero rest mass is[18] (where formulae for the scalar and vector fields are also given) obtain

$$<\Phi|\Phi> = \int_V \left\{ \Phi^\star i\gamma_4 \left(\frac{\partial}{\partial t} \hat{\varepsilon} \Phi \right) - \frac{\partial}{\partial t} \Phi^\star i \hat{\varepsilon} \Phi \right\} dV \qquad (16)$$

γ is the Dirac matrix and $\hat{\varepsilon} = +1$ for the particle and $\hat{\varepsilon} = -1$ for the anti-particle. Then equation (14) is of the form

$$\left\{ \Lambda_\mu \frac{\partial}{\partial X_\mu} + <\Phi|\Phi> \right\} \Phi = 0 \qquad (17)$$

This non-linear integro-differential equation is, in our opinion, fundamental and should describe all properties and interactions of particles. From such equations the mass spectrum is obtained as solution of a Sturm-Liouville type problem while solution of the stability problem gives the life time. In this theory all interactions and particles generations (packets splitting) are consequences of the mutual diffraction of these packets due to non-linearity. Analytical solution of such problems requires some new mathematical methods. In order to simplify the solution of eq. (17) one might demand the particle to be a point ; in that case $m = \Phi^+ \Phi$ and the equation takes the form

$$\left(\Lambda_\mu \frac{\partial}{\partial X_\mu} + \Phi^+ \Phi \right) \Phi = 0 \qquad (18)$$

We are not concerned here with the problems of physical interpretation and related ones, we only point out that the latter equation is of the same type as the main equations of the non-linear Heisenberg's theory[9].

To transform from equation (12) of a free particle to the equation describing the particle's motion in the electromagnetic field A_μ we perform (in analogy with classical physics) the transformation $\frac{\partial}{\partial X_\mu} \to \frac{\partial}{\partial X_\mu} - i e A_\mu$. Thus we have

$$\left(\frac{\partial}{\partial t} + \vec{v} \frac{\partial}{\partial \vec{X}} - i L \right) \Phi = 0 \qquad (19)$$

where $L = m\gamma + e\gamma U_\mu A_\mu$ is the relativistic Lagrangian. The generalization to the case of motion in the external field does not change the linear dispersion law eq. (3) but v and $C = \frac{L}{\hbar}$ will become dependent upon coordinates and time. The wave function, i.e. the solution of eq. (19), will have the form

$$\Phi = e^{-i \int L \, dt} f(\vec{X} - \int \vec{v} \, dt) \qquad (20)$$

The linear character of the dispersion implies that the wave packet will not smear out (more exactly, it will periodically appear and disappear). Then the only difference from the free motion will consist in the fact that the wavelength of the envelope will now be a function of coordinates and time.

For the case of nonrelativistic motion we perform the ordinary transformation from the relativistic wave function to the non-relativistic one $\Phi \to \Phi e^{-i \cdot m t}$. By this substitution eq. (19) and its solution (eq. (20)) do not change their form if L is considered as the nonrelativistic Lagrangian. We point out that the role of phase for the wave function is that of the classical action function S. This allows to establish a connection between classical mechanics and the theory developed here. Let us present the wave function in the form $e^{iS} f(\vec{X} - \int \vec{v} \, dt)$ and substitute it into eq. (19). Then we obtain for S :

$$\frac{\partial S}{\partial t} + \vec{v} \vec{\nabla} S - L = 0 \qquad (21)$$

Taking Hamilton-Jacobi theory as a guide, let us put $\vec{p} = \vec{\nabla} S$, then eq. (21) yields the Hamilton-Jacobi equation :
$\frac{\partial S}{\partial t} + H = 0$; where $H = \vec{p}\,\vec{v} - L$ is the Hamiltonian of the particle. Further it is possible to find the function S which depends on particle's coordinates, physical parameters entering the

Hamiltonian and on q nonadditive integration constants and then finally to solve the mechanical problem. The condition $\vec{p} = \vec{\nabla} S$ means that the passage to classical mechanics is performed in the "ray" limit. Using the analogy with optics, this procedure corresponds to the limit of geometrical optics when it is possible to introduce the concept of particle's trajectory, or ray. These objects are orthogonal to any given surface of constant action or constant phase. On the other hand the quantum object becomes a classical one as a result of collection of many wave packets f(t). It is physically inconceivable that all packets which make up a body come together and disappear simultaneously due to different packet velocities. Therefore, on the average, this combination generally would become a stable and invariable object which moves in accordance with the laws of classical mechanics whereas each elementary object obeys the quantum laws. Let us consider briefly the hydrogen atom. With the help of solution of classical problem about the particle motion in the central field let us write down the wave function eq. (20) in the following form :

$$\phi = e^{-iEt}\, e^{i\int_{r_0}^{r} p_r dr}\, e^{i\int_{\phi_0}^{\phi} p\phi d}\, e^{i\int_{\phi_0}^{\phi} p\phi d\phi}\, f(r - \int_0^t v_r dt\ ;\ \phi - \int_0^t \phi\, dt)$$

Here r_0 and ϕ_0 are the values of particle's coordinates (radius and angle respectively) at time t = 0. It is quite natural to accept as stationary orbits those which have the envelope as a standing wave, i.e. $ET = 2\pi n_1 h$; $\oint p_r\, dr = 2\pi n_2 h$; and $\oint p\phi\, d\phi = 2\pi n_3 \hbar$ where n_1, n_2, n_3 are integers. These conditions coincide with the Bohr-Sommerfeld quantization conditions.

The connection of approach developed here with the Schrödinger equation follow from the equation (20). The envelope may be identified with de Broglie wave and consequently satisfies the Schrödinger equation. The probabilistic interpretation of the envelope will be discussed in the third Section.

In conclusion of this Section let us find matrices Λ_μ. Suppose that the matrices Λ_μ are linear velocity functions, or

$$\Lambda_\mu = \Lambda_{\mu 0} + \Lambda_{\mu\nu} U_\nu$$

where $\Lambda_{\mu 0}$ and $\Lambda_{\mu\nu}$ are numerical matrices. Let us act on equation (14) by the operator $\Lambda_\sigma \frac{\partial}{\partial X_\sigma} - m$ from the left

$$\left\{\frac{1}{2}\left(\Lambda_\mu \Lambda_\sigma + \Lambda_\sigma \Lambda_\mu\right) \frac{\partial^2}{\partial X_\mu \partial X_\sigma} - m^2\right\}\phi = 0 \tag{22}$$

Let us require each component of the system (22) to satisfy the second order equation (13) ; then

$$\Lambda_\mu \Lambda_\sigma + \Lambda_\sigma \Lambda_\mu = -2\, U_\mu U_\sigma I \tag{23}$$

The conditions (23) are fulfilled if the numerical matrices $\Lambda_{\mu\nu}$ are ten 32 x 32 Hermitian matrices which satisfy the following commutation relations

$$\Lambda_{\mu\nu}\Lambda_{\sigma\tau} + \Lambda_{\sigma\tau}\Lambda_{\mu\nu} = 2(\delta_{\mu\sigma}\delta_{\nu\tau} - \delta_{\mu\tau}\delta_{\nu\sigma})I \tag{24}$$

The indices μ, ν, σ, τ take sequentially the values 0, 1, 2, 3, 4. If the 4-velocity in matrices Λ_μ is assumed zero $U_\mu = 0$ then the equation (14) reduces to the Dirac equation.

3. Interpretation of Unitary Quantum Theory

a) The Non-relativistic Case

The envelope of the function Re $\phi(X, t)$ describes the change of the field of the moving packet. In the solution obtained there are points where the packet disappears (Re ϕ = 0) and the energy of the particle remains in the form of harmonic components which create vacuum fluctuations in every point of space-time. The magnitude and the time instant of the occurrence of the fluctuation or background at every point do not depend on the distance from the particle which has disappeared. This is not however in contradiction with the relativity principles, since the ensueing background does not transmit information. The real world consists of a tremendous number of particles moving with different velocities relative to each other. Partial waves of such disappearing particles add up and give rise to real fluctuations which change in a most random way. In such a system some random particles are found, the appearance of which is due to the energy of the harmonic constituents of other disappearing particles. The number of these "particles of no scruples" changes constantly. They suddenly appear in order to disappear for ever, since the probability of a situation favourable for their reappearance is very low. It is not unlikely that all particles exist owing to each other. It is obvious that the number of particles in such a theory is not conserved and all processes which take place are random in nature.

The hypothetical measuring device and microprobe mentioned above cannot be obtained in practice, since all the measuring devices are macroscopic. At the output of any apparatus which is an unstable threshold macrosystem some macroscopic phenomena always take place, such as drops of fog in the Wilson camera, the blacking of photoemulsion grains, the formation of ions in the Geiger counter, the photo effect, etc. In macrodevice of any type the atomic nuclei and the electronic shells are close together and form a stable system. This system is no capable of assuming all imaginable configurations. The nature of the stable state allows rather numerous but discrete series of states. The transition from one such state to another one is a quantum jump. Hence, the absorption and emission of energy between atomic systems takes place in quanta and this is the consequence of the structure of matter. However, it does not mean that a quantum or a particle moving from one quantum-mechanical system to other propagates as something unchanging and indivisible. The energy of a particle may split and vary owing to vacuum fluctuations and external field, but the measurement conditions are such that we can detect only certain kinds of particles.

Any measurement, finally, is based on the energy exchange and is an irreversible process. Hence, a particle influences the state of the macrodevice, losing a quantum of energy θ or acquiring it in a reverse device. The best measuring device is one in which the discrete threshold energy is minimal. In hypothetical measurements $\theta = 0$, in this case the observer's measuring devices does not influence the particle and such a device would have 100% efficiency and record the vacuum fluctuations.

Let us consider the interaction of a particle with the macrodevice. The energy of the particle changes periodically with a frequency ω_B. Besides vacuum fluctuations are randomly superimposed and also vary the particle energy. In order to detect the particle by a device it is necessary to "wait", until the sum of the particle energy $Re^2\,\Phi$ and the energy of vacuum fluctuations ε will exceed the threshold θ :

$$\varepsilon + Re^2\,\Phi \geqslant \theta$$

The value of the fluctuation energy ε depends on the total number of particles in the Universe and is created by disappearing particles. The contribution of a separate partial wave to the

resulting background in each point is a random infinitesimal quantity (which may have any distribution) and in accordance with the central limiting theorem of Lyapunov the sum of vacuum fluctuations from the tremendous number of partial waves will have the normal distribution with maximal entropy. The probability P of vacuum fluctuations with energy exceeding ε_0 is

$$P = \frac{1}{\sqrt{2\pi}\,\sigma}\int_{\varepsilon_0}^{+\infty} \exp -\left(\frac{\varepsilon^2}{2\sigma^2}\right) d\varepsilon \qquad (25)$$

The variance σ depends on the number of particles in the Universe and in our case is supposed to be constant. This theory requires the finiteness of σ and, consequently, the Universe should be finite. By means of Moivre-Laplace formula and eq.(25) it is easy to obtain the detection probability of particles :

$$P = \frac{1}{2}\,\mathrm{erfC}\,\frac{\theta - Re^2\,\Phi}{\sigma^2} \qquad (26)$$

From the latter formula one can see that the detection probability of particle depends on the sensitivity of the measuring device.

Thus, the proposed approach leads to the conclusion that the relation $E = \hbar\omega$ is correct only on the atomic level. So there may exist particles (after splitting on a mirror) of the same frequency but different amplitudes of packets Φ and different detection probabilities. One particle, split on the mirror or the lattice, may be detected in several points simultaneously while another completely vanishes leaving no traces and only contributes to vacuum fluctuations.

The uncertainty correlation is the consequence of the fact that the energy and the momentum have no fixed values, but change due to periodic disappearance and reappearance of the particle. Furthermore, as a consequence of the statistical laws of measurement these values cannot be measured exactly because of the essentially unpredictable vacuum fluctuations. On the other hand, the center of the wave packet has exact coordinates, momentum and energy for the hypothetical observer at a given instant of time. But neither the hypothetical observer nor we ourselves predict their values at the next instant of time, and we (the macroobservers) have even no facilities to measure them exactly, as the measurement process by a macrodevice is statistical in nature.

The vacuum fluctuation makes the laws of the microworld essentially statistical for any observer. The exact prediction of future events requires exact knowledge of the vacuum fluctuation in any point at any instant of time, but this is impossible as in this case it is necessary to have information about the behaviour and structure of all the various packets in the Universe and to control their motion. "If -as W. Heisenberg writes in [10]- we want to know why α -particle was emitted at that particular time we would have to know the microscopic structure of the whole world including ourselves, and that is impossible". Therefore it may be considered that Laplace determinism in microphysics of the present and future is lost once and for all. An analogous point of view on the origin of probability in quantum mechanics has been expressed by Feynman [11] : "Almost without doubt it (probability - L.S.) arises from the need to amplify the effects of single atomic events to such a level that they may be readily observed by large system".

The envelope of partial waves which arises as a result of linear transformations of the wave packet and also of its splitting and dividing satisfies the Huygens principle. This explains the possibility to relate formally with the moving particle the flat monochromatic de Broglie wave, which as if were propagated in the direction of travel, and all the wave properties of particles (interferences, diffraction, etc.).

For a complete reversibility of the quantum phenomena under replacing +t by -t it is necessary not only to reproduce the amplitude and the form of the packet which existed at time +t, but also to reestablish the vacuum fluctuation which existed at that time. The equation of unitary quantum mechanics allow replacement of +t by -t with simultaneous substitution of Φ for Φ^*, or the formal reversibility (the reproducibility of the amplitude and form of the packet). But this reversibility does not exist in nature even for the hypothetical observer, because for the restoration of the previous vacuum fluctuations all processes in the Universe should be reversible, and that is impossible. However, it may be considered that reversibility in quantum mechanics is statistical, i.e. individual processes may be reversible with only certain probability.

The function Φ is strictly monochromatic, but does not exist as a real, flat, travelling wave. And although Φ is related with the energy of the particle it can also be related with such concepts as "probability waves", "the information field", and "knowledge waves". The wave function is meaningful

for an isolated system, as has been stated by A.D. Alexandrov and V.A. Fock [12], but it can be detected only by numerous identical experiments although the hypothetical observer may measure it for a single particle. It will be noted that the envelope is at rest in all the inertial frames of reference and the wavelength alone changes.

Generally speaking, the function Φ may be related with the wave function Ψ_* of quantum mechanics, but the quantity $Re^2\ \Phi$ differs from $\Psi\Psi^*$ not only in rapid oscillations. The energy of the particle is related with function $Re^2\ \Phi$, whereas $\Psi\Psi^*$ is related only to probabilities.

Contrary to conventional quantum theory, in this approach the concept of phase plays an essential rôle. For example, if a particle approaches a potential barrier in the phase of complete disappearance ($Re\ \Phi = 0$), then due to its linearity and superpositions for small Φ it will pass through rather narrow barrier without interaction. On the other hand, for the phase giving the maximal value of $Re\ \Phi$ the interaction will take place due to the non-linearity and the particle may be reflected. This point of view predicts a new effect : let the flow of monochromatic particles fall on the chain of periodic (with period a) rather narrow (compared with λ_B) potential barriers. Then an anamalous tunneling effect should be observed when $\lambda_B = 2a$, which is not predicted by conventional quantum theory [13,14].

b) <u>The relativistic Case</u>

Analysing eq. (10) we see that Φ contains an oscillating term with a frequency $\omega_S = \frac{mC^2}{\hbar\gamma}$ which is the Schrödinger "Zitterbewegung". The physical significance of this very rapid oscillating process is the following : after the Creator has stirred up the "medium" and has created the wave packet, the latter began to oscillate with a frequency ω_S like a membrane or a string. If the wave packet begins to move, the de Broglie vibrations with a frequency $\omega_B = \frac{mv^2}{\hbar\gamma}$ arise because of the dispersion. At low energies $\omega_S \gg \omega_B$ and the fast natural oscillations do not influence the experiment and all quantum phenomena are determined by the de Broglie vibrations.

With the increase of energy the frequency ω_B approaches ω_S and the resonance phenomenon will lead to an increase of the oscillation amplitude in accordance with eq. (11) and to the growth of the mass. Furthermore, the periodical disappearance and appearance of the particle will be going on with the difference frequency $\omega_d = \omega_S - \omega_B = \frac{mC^2\gamma}{\hbar}$ and the particle will acquire the low frequency envelope with the wavelength $L \approx \frac{h}{mC\gamma}$. Within the ultrarelativistic limit the wavelength L becomes much greater than the characteristic dimensions of the quantum system with which it interacts. Therefore, the particle is represented as a quasi-stationary wave packet moving in accordance with classical laws. This explains the success of applying the hydrodynamic theories to multiple particle production. But such processes are not the property of particles of high energies alone. They also take place when the energies are low, but the largest number of particles generated is below the threshold and, hence, is unobservable.

4. Possible Experimental Proofs and Implications

The theory developed here will remain a play of fancy if the following effects are not found experimentally.

1. Let a very weak source emit a beam of N particles per second. If a shutter is placed in front of the source and opens for a short period of time $\tau \ll N^{-1}$, then it is most probable that no particles will pass through it during this time or just a single particle will pass through. Let these particles fall at an angle of 45° on a semitransparent mirror. In conventional quantum mechanics the particle either passes through the mirror or is reflected. According to the proposed approach the packet splits up on the mirror and enters each of the particles beam, which depend on the phase of the packet at the mirror and the structure of the mirror at that point. In a general case, we have two different wave packets (subthreshold particles) with smaller amplitudes. No change of frequency ω in the formula $E = \hbar\omega$ (redshift) takes place as all the processes are linear i.e. they do not depend on the amplitude. This being the case the particle energy $Re^2 \phi$ reduces and the detection probability of particle is also decreased. (A large vacuum fluctuation is necessary, but the probability of its occurrence is low). Consequently, as a result of measurement particles sometimes disappear or two particles can be observed instead of one. The creation of several particles from one is not in conflict with the law of the energy conservation as the energy of the subthreshold particle may be increased up to the necessary value by the fluctuations.

A similar experiment with photons was first made by

M. Cosyns [15] who placed photomultipliers in each of the pencils of rays and showed that there are cases in which coincidences are registered. For the explanation of this experiment which does not agree with the principle of complementarity, an assumption was made that such coincidences result from independent photons which are quite random to one another and follow one another in short intervals of time. Unfortunately, he did not try a statistical verification of this assumption. At the present time we have a funny situation. A great number of similar experiments have been carried out (such as Brown-Twiss's experiments [16-17]) which led to the conclusion that particles always have a definite tendency to come into detectors in correlated pairs. This result confirms the proposed formulation. But it is curious that for the explanation of these experiments contradicting conventional quantum mechanics physicists invent saving mechanisms such as coherent states.

2. Let us suppose that monochromatic particles with energy $E \geqslant \theta$ take part in diffraction experiments. If a single particle diffracts it creates an interference pattern, but it cannot reveal itself in i maxima, since the packet energy in them is $E_i \ll \theta$. If n coherent particles take part simultaneously in the interference, then the energy in the maxima may increase because of the superposition of the fields of different particles and in this case the device may respond. Thus, the interference pattern made up by particles is used instead of a beam. This has been observed in experiments [19] which so far have not been satisfactorily explained. In the case of $E \gg \theta$ as in experiments [20] this effect does not take place.

3. The transmission coefficient of coherent particles of very low energies ($\lambda_B \cong 5$ Å) through a chain of periodic potential barriers (a monocrystal) is maximum when $\lambda_B = 2a$, where a is the lattice constant of the monocrystal target. A similar but much weaker effect must go on again at ultrarelativistic energies when $L = 2a$. These experiments will require a flow of monoenergetic and phase-synchronized particles. Such a flow can be obtained by separating a narrow beam of monoenergetic particles reflected from the crystal.

4. So long as the slowly changing part of space-time forms a field and the local bunch of this field represents a particle such a theory cannot contain areas or regions of space in which the laws of the field do not hold. The really existing irremovable vacuum fluctuation in this theory will not be invariant under

rotations, translations, space and time reflections, and other transformations ([21]) and, consequently, the conservation laws determined by them will be nonlocal and approximate. This takes place most easily when the particle energy $Re^2\ \Phi$ is of the same order as the variance σ of the vacuum fluctuation. But, unfortunately, these processes take place near threshold and they are difficult to observe.

5. Since some particles may appear spontaneously from the vacuum or disappear into it at very low probabilities, all the elements will show a quite new type of nuclear transformations : any element may transform into its isotrope or into one of its nearest neighbours in the Mendeleev periodic table. This was at one time pointed out by Rutherford ([22]) and these processes have indeed been found in Geology although they are inexplicable ([23]).

6. When some particles collide the effects of particles penetration through one another without any interaction must be observed in cases when one or both of the particles vanish at the point of collision. This seems to be illustrated by S-states of atoms.

CONCLUSION

The proposed outlines of unitary quantum mechanics of a single particle based on a unified field are extraordinarily simple from the point of view of a hypothetical observer. A hypothetical observer "can always measure" the amplitude of the wave function, but we are not in a position to do so and shall have to be satisfied with only a probabilistic interpretation of the wave function. However, we must bear in mind that this interpretation implies a very simple mechanism which explains quantum phenomena and reduces the description of entire nature to some unified field, in the continuous transformations of which the wonderful variety of observable phenomena are seen.

In spite of mathematical difficulties the quantum theory will cease to be riddle and Feynman's sincere words ([24]) "... I can safely say that nobody understands quantum mechanics" - will belong to history.

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