The Quantum Dynamics of Natural Distributed Oscillatory Systems

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***Abstract*—A statistical method for the quantization of natural electromagnetic (NEMOS) and electron-positron (NEPOS) oscillatory systems is discussed. The Wheeler-Feynman's concept of "direct interparticle action" for the quantum radiation-absorption is generalized to the Coulomb interaction. The energy-momentum conservation is postulated as a fundamental law forbidding any objective their "uncertainty". The spatial (spatio-temporal) localization of NEPOS wavepackets and the Heisenberg's "uncertainty principle" are supposed to be a result of a permanent interaction of NEPOS and NEMOS, i.e., the stochastic exchange with random quanta of momentum (or energy-momentum) between ones. The absence of "zero-point oscillations" of the natural oscillatory systems is asserted. The new physical sense of De Broglie wavefunctions is illustrated with the simplest quantum systems "electrons in potential wells".**

***Keywords*—De Broglie wave; distributed oscillatory system; energy-momentum; second quantization; zero-point oscillation**

I. Introduction

The further development of millimeter and submillimeter electronic technologies, in our opinion, may be linked with the progress in the nanotechnology. Solitary microwave, quasi-optical and quantum devices will be replaced with clusters of microscopic coherent nonlinear oscillators penetrated by "blood vessels" of power buses and heat sinks as well as "nervous system" of control circuits. Such cells will form active phased arrays of intricate shapes used as "radiating" or "absorbing" materials. The integrated power of such devices is proportional to their volumes, so, is not limited…

New physical phenomena may be used for creating the nonlinearity, like the tunnel effect in vacuum gap. Because a characteristic size of such cells is much less than 1 micrometer (this enables their functioning at the atmospheric pressure), the design of those must be performed according to the laws of quantum mechanics and quantum electrodynamics. But, in spite of striking achievements in the engineering applications of these disciplines, there is no consensus in understanding of the theoretical bases of quantum world behavior yet.

Concepts of natural electromagnetic (EM) and electron-positron (EP) oscillatory systems (NEMOS, NEPOS) as real physical bases for De Broglie matter waves were proposed in [1] and [2] respectively. Those are alternatives to the "physical vacuum" of the quantum electrodynamics [3]. The second quantization of NEMOS and NEPOS was described in [4] in brief. In this paper, that problem is discussed in more detail.

II. Natural Distributed Oscillatory Systems

There are three kinds of natural distributed oscillatory systems differing in the number N of their generalized coordinates: 3-vector (fermion) system with $N=3$; 4-vector (EM) system with $N=4$; and 4-tensor (gravitational) system with $N=10$. Because of additional relations (like the Lorenz gauge), the numbers of fully independent generalized coordinates N_i are of 2, 3, and 5 respectively, therefore, corresponding maximal spins of quanta s are of 1/2, 1, and 2 respectively according to the known relation $N_i = 2s+1$ [3].

The natural distributed oscillatory systems differ also in their cutoff wavenumbers k_0 determining kinematics and dynamics of wavepackets. These relativistic scalars are full-value replacements for the Newton's "particle rest masses" concept. All 3-vector systems have $k_0 \neq 0$, so, their wavepackets are "particles" (or, more strictly, quasi-particles) with non-zero "rest masses" (leptons, quarks and neutrino). For 4-vector and 4-tensor systems $k_0 = 0$, accordingly, quanta of EM and gravitation interactions have no "rest masses".

III. Electromagnetic and Electron-Positron Oscillatory Systems

Let's generalize both the EM potential 4-vector and the De Broglie EP wavefunction as some real-valued aleph-functions $\vec{\aleph}^{\gamma}(t,x,y,z)$ and $\vec{\aleph}^{e}(t,x,y,z)$ respectively. EM aleph-function $\vec{\aleph}^{\gamma}$ is a 4-vector constrained with the Lorenz gauge $\vec{\nabla}\cdot\vec{\aleph}^{\gamma}\equiv 0$, where $\vec{\nabla}\cdot\vec{\aleph} = \partial\aleph_t/\partial t + \partial\aleph_x/\partial x + \partial\aleph_y/\partial y + \partial\aleph_z/\partial z$ is the 4-divergence ($\vec{\aleph}^{\gamma}$ differs from the EM potential 4-vector $\vec{A}$ only in the measure unit). EP aleph-function $\vec{\aleph}^{e}$ is also 4-vector constrained with both the Lorenz gauge $\vec{\nabla}\cdot\vec{\aleph}^{e}\equiv 0$ and a spatial 3-solenoidality ("media incompressibility") condition: $\aleph^{e}_{t}\equiv 0$ in the rest system of coordinates. In contrast to $\vec{\aleph}^{\gamma}$, $\vec{\aleph}^{e}$ has no "potential" eigenfunctions (with spin zero) in its Fourier expansion, therefore, spins of NEPOS modes are of $\pm 1/2$, not of $-1,0,+1$ as for NEMOS.

The physical senses of $\vec{\aleph}^{\gamma}$ and $\vec{\aleph}^{e}$ are local deviations of NEMOS and NEPOS respectively from their "undisturbed" states along respective coordinate axes. According to such

interpretation, both $\vec{\aleph}^{\gamma}$ and $\vec{\aleph}^{e}$ must be gauge-dependent (i.e., to tend to zero far off from a matter), but this is insignificantly in the quantum theory, because any invariable in the space-time addition to $\vec{\aleph}^{\gamma}$ or $\vec{\aleph}^{e}$ has zero energy-momentum quantum, so, cannot be involved in the interaction.

"Stiffness factors" R_{γ}, R_{e} couple the local shifts of NEMOS and NEPOS in some point with 3-densities of energy-momentum in this point (like $1/\mu_0$ factor does for the EM potential), i.e., 3-densities of the Lagrange function for the non-interacting systems may be written respectively as:

$$\lambda^{\gamma} = \frac{R_{\gamma}}{2}\left[-(\vec{\nabla}\aleph_t^{\gamma})^2 + (\vec{\nabla}\aleph_x^{\gamma})^2 + (\vec{\nabla}\aleph_y^{\gamma})^2 + (\vec{\nabla}\aleph_z^{\gamma})^2\right];$$

$$\lambda^{e} = \frac{R_{e}}{2}\left[k_{0e}^2(\vec{\aleph}^{e})^2 - (\vec{\nabla}\aleph_t^{e})^2 + (\vec{\nabla}\aleph_x^{e})^2 + (\vec{\nabla}\aleph_y^{e})^2 + (\vec{\nabla}\aleph_z^{e})^2\right],$$

where $\vec{\nabla}\aleph_{\tau} = \{\partial\aleph_{\tau}/\partial t, \partial\aleph_{\tau}/\partial x, \partial\aleph_{\tau}/\partial y, \partial\aleph_{\tau}/\partial z\}$ is the 4-gradient; the braces mean the combining of scalar values into a vector; τ is a generic symbol for *t*, *x*, *y*, or *z*.

IV. The Quantum Dynamics of NEPOS and NEMOS

There are two methods for a distributed oscillatory system excitation, known as "parametric" and "force" ones. The former is based on varying the system eigenfunctions by an external influence. The latter does not change the eigenfunctions, but varies the occupation numbers of normal modes of the system. The difference is noticeable, e.g., for atomic systems. "Parametric" approach assumes that the stationary electron shells are new eigenmodes of NEPOS, which was "deformated" by the static EM potential of the nucleus. The "force" point of view explains the spatial localization of the electron shell as a result of permanent exchanging with random quanta of momentum between the nucleus and the "electron" via NEMOS, so, the stationary electron shells are only forced modes (wavepackets) of NEPOS, not eigenmodes. We accept the "force" approach as more consistent with the quantum principles.

Our postulate is: the energy-momentum conservation is a fundamental law of the Universe; any objective "uncertainty" for ones is impossible. E.g., for an isolated physical system "charged particle in its own EM potential", the total energy-momentum is objectively strictly defined. The uncertainty has a place only in what part of this energy-momentum may be found as located in NEPOS and what part of one as reside in NEMOS at the specific measurement. Also, mechanism of the quantum EM interaction is supposed to be the same for both the time-dependent (e.g., radiating-absorbing atoms) and the static (e.g., mutually repulsive "electrons") systems.

The interaction process cannot be described in the temporal domain (consequently, also in the spatial one) in principle [3]. So, the Lagrange equations for NEMOS and NEPOS (the wave equation and the Klein-Gordon equation respectively) can be written only for their non-interacting (free) vibrations. However, free oscillations of NEMOS and NEPOS do not occur at all. "Pure" eigenmodes of these systems cannot be excited as having infinite spatio-temporal spread. On the other hand, harmonic components of localized wavepackets are not independent (because energies-momenta of the components taken separately do not satisfy the quantization principle). So, localized NEPOS wavepacket ("electron") is linked together by permanent interaction of its spectral components with each other by means of NEMOS.

Thus, the spatial localization of NEPOS wavepackets and the Heisenberg's "uncertainty principle" both are results only of NEPOS and NEMOS interaction. E.g., a sole NEPOS wavepacket in its "own" EM potential stochastically exchanges with NEMOS by random quanta of momentum (not energy) producing continuous $\vec{\aleph}^{e}$ spectrum of finite width in the spatial domain. The energy-momentum spectral density describes the probability that respective (*m*-th) eigenmode has a non-zero occupation number $K_m = 1$.

The "associated" with "electron" NEMOS wavepacket has similar (mirrored) spectral envelope ensuring total energy-momentum conservation. Wavenumbers of its harmonics are the differences between wavenumbers of NEPOS wavepacket harmonics. So, an essential distinction exists between the both spectra. The "central" wavenumber in the spectrum of moving NEPOS wavepacket is proportional to average energy-momentum of the "electron", therefore, this is not zero. But the "central" wavenumber in the spectrum of the "coupled" NEMOS wavepacket is zero. So, the spectrum of $\vec{\aleph}^{\gamma}$ is the mirrored spectrum of $\vec{\aleph}^{e}$ transferred to the zero "central" wavenumber. This means that the EM potential of a single "electron" does not have energy-momentum. After the inverse Fourier transform, both the spectra provide spatially localized functions $\vec{\aleph}^{e}$ and $\vec{\aleph}^{\gamma}$; $\vec{\aleph}^{\gamma}$ is a "slow envelope" of $\vec{\aleph}^{e}$.

The interaction between the harmonic components of NEPOS and NEMOS wavepackets occurs just in whole 4D Universe, so, the transferred energy-momentum quantum is strictly defined. However, this stochastic process cannot be investigated, because it takes a place "over" the space-time. Only whole wavepackets, produced by the interference of their harmonics, can be observed in experiment. The reason for a quantization of NEMOS integral deviation, causing imaginary existence of the "elementary charge", is not explained yet.

If two or more immovable "electrons" are located in their "common" EM potential, in addition to the "localizing" effect for each wavepacket taken separately, NEMOS performs a mutual stochastic exchange with momentum quanta between the "particles", i.e., the Coulomb repulsion. For moving "electrons", this exchange may include also energy quanta.

Similar process in the time domain transfers both energy and momentum and is known as "radiation-absorption". We must put into our hypothesis the Wheeler-Feynman's concept of "advanced" EM interactions along with "retarded" ones [5,6] to explain the temporal localization of EM wavepackets that transfers energy. The "advanced" NEMOS eigenmodes with $k_{\gamma t} < 0$, containing quanta of negative energy, must be treated as some "antiphotons", whereas "retarded" ones with $k_{\gamma t} > 0$ are the "ordinary photons" of positive energy.

The magnetic moment of "electron" is, probably, also similar result of the "uncertainty" in its own angular momentum. Stochastic changes of direction of the "electron rotation axis" are "compensated" by "mirror" variations in angular momentum of NEMOS.

A new physical sense must be supposed for the electric current density 4-vector $\vec{j}(t,x,y,z)$. It is treated now as a factor (rate) of energy-momentum interchange between localized wavepackets of NEPOS and NEMOS, not as real physical object having energy-momentum. After the second quantization, $\vec{j}$ turns into a part of an operator that "shifts" the nonzero occupation number between different eigenmodes of NEPOS and NEMOS. The spatio-temporal components of $\vec{j}$ are proportional to the respective components of the central wavenumber $\vec{k}_e$ of NEPOS wavepacket. Wavenumbers of $\vec{j}$ harmonics are the differences between wavenumbers of harmonic components of NEPOS wavepacket. A hypothetic "pure" NEPOS eigenmode would not create $\vec{j}$ at all.

V. What Are the Zero-Point Oscillations?

The above concept generally adjusts with [3] except for a one point. Our hypothesis does not assume existence of the zero-point oscillations for neither NEPOS nor NEMOS taken separately. Respectively, the energy-momentum levels of their *m*-th eigenmodes start from zero, not from $h\vec{k}_m/2$, where $h = c\hbar$. To explain this mismatch, let's remember how the second quantization of EM potential performs in [3]. Using the wave equation for $\vec{\aleph}^{\gamma}$ and the Fourier method

$$\vec{\aleph}^{\gamma}(t,x,y,z) = \sum_{m=-\infty}^{\infty} u_m(t)\vec{\aleph}^{\gamma}_m(x,y,z),$$

a Lagrange equation $d^2u_m/dt^2 + k_{mt}^2 u_m = 0$ is derived for *m*-th eigenmode instantaneous value u_m (*t* is assumed as *ct*; *c* is the light velocity). This equation is similar to the mechanical quantum harmonic oscillator (QHO) Lagrange equation, so, the Hamilton function of *m*-th eigenmode is written as

$$\mathrm{H}_m\left(u_m, \frac{du_m}{dt}\right) = \frac{R_{\gamma}}{2}\left[\left|\frac{du_m}{dt}\right|^2 + k_{mt}^2|u_m|^2\right]\int_V \left|\vec{\aleph}^{\gamma}_m\right|^2 dxdydz,$$

where the integral is taken over all 3-volume of the Universe. The Hamilton operator for *m*-th eigenmode

$$\hat{\mathrm{H}}_m\left(\hat{U}_m, \hat{P}_m\right) = \frac{R_{\gamma}}{2}\left[\left(\hat{P}_m\right)^2 + k_{mt}^2\left(\hat{U}_m\right)^2\right]\int_V \left|\vec{\aleph}^{\gamma}_m\right|^2 dxdydz$$

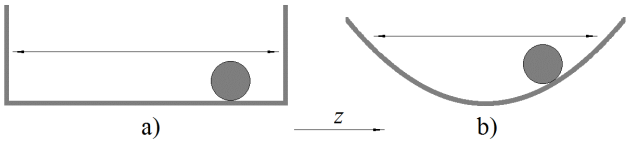

Fig. 1. "Classical" models of "electrons" (NEPOS wavepackets) in rectangular (a) and parabolic (b) potential wells.

is similar to the Hamiltonian of mechanical QHO. For this reason, the energy spectrum of $\hat{\mathrm{H}}_m$ is "declared" as coincident with the spectrum of mechanical QHO:

$$W_m(K_m) = hk_{mt}\left(K_m + 1/2\right).$$

An error has a place in such reasoning. In order to the eigenvalue spectrum of $\hat{\mathrm{H}}_m$ coincides with the spectrum of mechanical QHO, the generalized momentum operator for *m*-th eigenmode must be written as $\hat{P}_m = -ih\partial/\partial u_m$. But such expression is not the generalized momentum operator. Moreover, there is no any physical sense in one because there is no function undergoing this operator.

A formal cause why the Hamilton operators mismatch, while the Hamilton functions are similar, is as follows. Generalized coordinates of mechanical QHO are the spatial coordinates; respective wavefunction is a function of *x*, *y*, *z*. On the contrary, wavefunctions of NEMOS $\vec{\aleph}^{\gamma}$ and NEPOS $\vec{\aleph}^{e}$ are also their generalized coordinates.

The zero-point oscillations exist only in "mechanical" oscillatory systems, where the generalized and the spatial coordinates coincide. Such systems (e.g., crystal lattices) always are based on the interaction between NEPOS and NEMOS. The zero-point energy $hk_{mt}/2$ is "inserted" into mechanical QHOs during the creation of ones.

The argument "contra" our hypothesis is the existence of the Casimir effect. However, an attempt of the interpretation of one without using the zero-point oscillations of vacuum is made in [7]. If that is right, the observations of the Casimir effect do not imply the reality of the zero-point energy.

If the cancellation of the vacuum zero-point energy is done, quantization rules for energy-momentum of natural oscillatory system eigenmodes may be expressed in a obvious form: shift of the system in any spatio-temporal direction over the respective wavelength must cause the value of action equal to *h*, changing the aleph-function phase by 2π.

VI. A Simple Example

Let's compare infinitely deep rectangular (Fig. 1, a) and parabolic (Fig. 1, b) 1D potential wells for an "electron" (NEPOS wavepacket) created by a system of external "well charges". As one can see, no principal difference between the both wells, except for the system total energy varies sharply or gradually with change of "electron" localization in *z* direction respectively. Because the energy in any case tends to infinity at $z \to \pm\infty$, the wavepacket shapes should not differ essentially for both the wells.

Note that, because both the systems are time-independent (stationary), a reversion from "energy" consideration back to the Newton's "force" description is suitable, where "force" is interpreted as quantized flow of momentum $d\vec{P}/dt$. So, well shape may be defined as dependence of dP_z/dt between the "electron" and the "well charges" on their relative position. dP_z/dt depends on the rate of mutually non-orthogonal

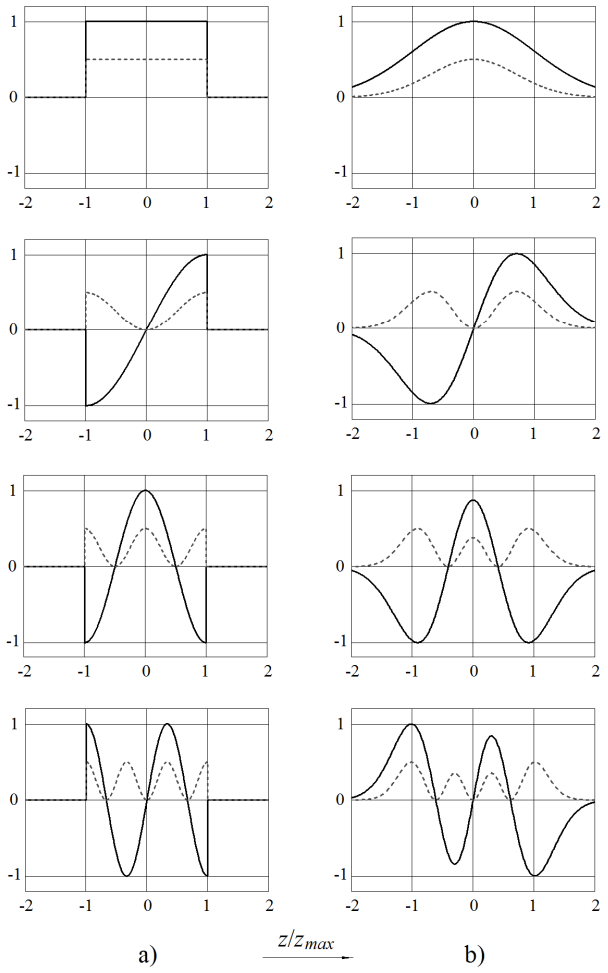

Fig. 2. The lowest NEPOS wavefunctions (solid) and their squares (dashed) for rectangular (a) and parabolic (b) potential wells.

positive and negative harmonics in spectra of the "electron" and the "well charges" wavepackets in z direction, which decreases as the wavepackets move away one from another.

The 3D solenoidality condition for fermion wavefunctions in the rest coordinate system $\partial \aleph_x^e / \partial x + \partial \aleph_y^e / \partial y + \partial \aleph_z^e / \partial z \equiv 0$ means that the boundary conditions for $\vec{\aleph}^e$ in the rectangular well must be "outwardly" similar to the ones for "magnetic field" in rectangular EM resonator. Normalized wavefunctions for $\aleph_x^e$, $\aleph_y^e$ and their squares for four the lowest $m_z = 0,1,2,3$ are plotted in Fig. 2, where (a) describes the rectangular well; (b) is for the parabolic one. A qualitative similarity of both kinds of the wavefunctions is obvious; the difference is only in "sharpness" of their decreasing with the distance. However, the aleph-function components $\aleph_x^e$, $\aleph_y^e$ for the rectangular well differ fundamentally from the Schrodinger's function $\Psi(t,x,y,z)$ behavior, which is zero at the walls.

There is only nondegenerate wavefunction with $m_z = 0$ in real (3D) rectangular well that is similar in appearance to *TE* (*H*) mode "magnetic field" of rectangular EM resonator with $m_x, m_y \geq 1$ and $m_z = 0$. Note that this similarity is apparent; functions in Fig. 2 are not NEPOS eigenfunctions, because all those are not harmonic in the z direction. Those are the NEPOS wavepackets. Only permanent exchange with momentum quanta between the "electrons" and the "well charges" via NEMOS can hold the "electrons" in the wells.

Now, the origin of the "zero-point oscillations" in QHO is understandable. The NEPOS wavefunction in the parabolic well is "smeared" over a finite area even for $m_z = 0$. Energy of "diffused particle" is greater than zero due to the parabolic energy dependence on z. But for taken separately NEPOS and NEMOS this mechanism does not work, so, there are no "zero-point oscillations" of vacuum.

VII. Conclusion

The existence of spatio-temporally localized wavepackets in natural electromagnetic and electron-positron oscillatory systems is possible due to the permanent interaction between NEPOS and NEMOS widening spectra of their modes and causing all oscillations to be forced, not natural. The zero-point oscillations of NEPOS and NEMOS "taken separately" do not exist; this effect is a specific feature only of "mechanical" oscillatory systems, based on the interaction between NEPOS and NEMOS. Treating "electrons" and "positrons" as excited modes of a real distributed oscillatory system assumes another physical sense of De Broglie wavefunction than scalar function Ψ in the "Copenhagen" interpretation. A respective 4-vector aleph-function $\vec{\aleph}^e$ is illustrated for the simplest quantum systems "electrons in potential wells".

The further development of our hypothesis may consist in treatment of the gravitation interactions as a quantum dynamics of a specific natural gravitational oscillatory system (NGOS) or ten extra quadratic ("flexural") degrees of freedom of NEMOS in addition to four linear ("displacing" and "torsional") EM ones, not as the space-time curvature.

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