

STOCHASTIC WAVE PACKETS OF NATURAL OSCILLATORY SYSTEMS

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De Broglie waves are interpreted as oscillations of generalized coordinates of natural oscillatory systems with distributed parameters (NOSs). The action four-scalar and the momentum-energy four-vector both are assimilated with the geometry of NOS eigenmodes in the Minkowski spacetime. A conservation law for the action is supposed as a necessary condition for the energy-momentum conservation. The Wheeler-Feynman's concept of "direct interparticle action" is developed for both the quantum radiation-absorption and the Coulomb interaction. The spatio-temporal localization of NOS wave packets and Heisenberg's "uncertainty principle" both are assumed to be results of stochastic exchange with action quanta between different NOSs. The simplest examples of NOS wave packets are given. Some outcomes of application of this theory to solid state phenomena are discussed.

Introduction

The quantum mechanics (QM) and the quantum electrodynamics (QED) [1] are the principal theoretic bases for nanoelectronics and nanotechnology. Despite striking achievements in the engineering applications of these disciplines, there is no consensus in theoretical understanding the quantum world behavior yet. Such opinion is confirmed by the existence of many interpretations of the quantum theory other than so-called "Copenhagen interpretation". Serious problems of the "Copenhagen school" are expressed in the best way in the notorious "Schrödinger's cat" paradox and David Mermin's "Shut up and calculate" sentence.

E.g., the Wheeler-Feynman's (and, earlier, Hugo Tetrode's) idea of "advanced" EM interactions along with "retarded" ones [2, 3] was recently reanimated by Yakir Aharonov, "patriarch" of contemporary quantum theory. Concepts of natural electromagnetic (EM) and electron-positron (EP) distributed oscillatory systems (NEMOS, NEPOS) respectively, as real physical bases for the de Broglie matter waves, were proposed by one of us in [4, 5]. Moreover, NEMOS and NEPOS are also alternatives to the "physical vacuum" of QED [1]. The statistical method of the second quantization of NEMOS and NEPOS (quantum dynamics and quantum statistics), as well as some additional problems of the electron waves and wave packets behavior in vacuum and matters, were discussed in [5] (see also references cited in one). The paper is the further development of a discipline named as "theory of natural oscillatory systems" (TNOS). The term "quantum" is not used advisedly, because TNOS is a quantum theory "in essence".

Theoretical Theses

The 4D pseudo Euclidean formalism with imaginary time is assumed in this paper. The Cartesian coordinate system is used; x , y , and z are the real spatial coordinates; t is a temporal coordinate with dimension of imaginary length, which is defined as product of the time, the light velocity in vacuum c , and the imaginary unit. Four-vectors in the Minkowski spacetime are mixed-valued with real spatial components and imaginary temporal one.

Instead of the EM potential four-vector and de Broglie EP wavefunction let's work with complex-valued four-vector aleph-functions $\vec{\aleph}^\gamma(x, y, z, t)$ and $\vec{\aleph}^e(x, y, z, t)$ respectively, each having real spatial components and imaginary temporal one. EM aleph-function $\vec{\aleph}^\gamma$ is restricted with the Lorenz gauge $\vec{\nabla} \cdot \vec{\aleph}^\gamma \equiv 0$ (note that $\vec{\aleph}^\gamma$ differs from the EM potential four-vector $\vec{A}(x, y, z, t)$ only in the measure unit). EP aleph-function $\vec{\aleph}^e$ is restricted with both the Lorenz gauge $\vec{\nabla} \cdot \vec{\aleph}^e \equiv 0$ and a spatio-temporal three-solenoidality ("media four-incompressibility") condition, namely, $\aleph_\xi^e \equiv 0$ in some "privileged" rest frame system, where ξ is one of the spatial coordinates (arbitrary). In contrast to $\vec{\aleph}^\gamma$, $\vec{\aleph}^e$ has no "potential" eigenfunctions (with spin of

zero) in one's Fourier expansion, therefore, according to the angular momentum quantization rules [1], spins of NEPOS eigenmodes are of $\pm 1/2$, not of $-1, 0, +1$, as for NEMOS.

The physical senses of $\vec{\mathfrak{N}}^\gamma$ and $\vec{\mathfrak{N}}^e$ are local deviations of NEMOS and NEPOS respectively from their "undisturbed" states along the respective coordinate axes. According to such interpretation, both $\vec{\mathfrak{N}}^\gamma$ and $\vec{\mathfrak{N}}^e$ 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 spacetime addition to $\vec{\mathfrak{N}}^\gamma$ or $\vec{\mathfrak{N}}^e$ has zero action, so, cannot be involved in any interaction.

TNOS is based on four main hypotheses:

1. "Hard" particles do not exist; all physical objects and phenomena are results of oscillations of some distributed NOSs along their generalized coordinates.

2. Quantization of total action of each NOS with interval of the Planck's constant η is a general principle of nature.

3. Cumulative action of all NOSs is an invariable value identically equal to zero.

4. A stochastic generation of equal numbers of positive and negative action quanta for different NOSs has a place as a set of "overspacetime" acts.

Let's suppose that just action, not momentum-energy, is a fundamental value, discrete with the quanta of η . The action discontinuity is the reason for the quantization of nature.

The total action of the Universe consists of mutually dependent (by means of the stochastic generation of additional positive and negative quanta) actions of all NOSs

$$H = \int_V \vec{\mathfrak{N}} \cdot \Lambda \vec{\mathfrak{N}} dx dy dz dt = L\eta, \quad (1)$$

where $\vec{\mathfrak{N}}(x, y, z, t)$ is the NOS four-vector wavefunction; Λ is so-called Euler-Lagrange operator, describing dynamics of a NOS by substitution in the Euler-Lagrange equation $\Lambda = 0$; V is the Universe four-volume; $L = 0, \pm 1, \pm 2, \dots$ is so-called NOS enforce number indicating how many positive or negative quanta of action keep the NOS away from its free oscillation (with $H = 0$).

The total action of each NOS can be evaluated also as an integral of the action four-density $h(x, y, z, t)$ (known as the Lagrange function [1] too) over the four-volume V :

$$H = \int_V h dx dy dz dt. \quad (2)$$

Relativistic invariants of three-densities of the Lagrange function $h(x, y, z, t)$ (or, the same, the action four-densities) [1] for non-interacting NEMOS and NEPOS can be coupled with the local deviations of these NOSs and their first-order derivatives in some point as respectively:

$$h^\gamma = \frac{i}{2} \left[(\vec{\nabla} \mathfrak{N}_x^\gamma)^2 + (\vec{\nabla} \mathfrak{N}_y^\gamma)^2 + (\vec{\nabla} \mathfrak{N}_z^\gamma)^2 + (\vec{\nabla} \mathfrak{N}_t^\gamma)^2 \right]; \quad (3)$$

$$h^e = \frac{i}{2} \left[(\vec{\nabla} \mathfrak{N}_x^e)^2 + (\vec{\nabla} \mathfrak{N}_y^e)^2 + (\vec{\nabla} \mathfrak{N}_z^e)^2 + (\vec{\nabla} \mathfrak{N}_t^e)^2 + k_e^2 (\vec{\mathfrak{N}}^e)^2 \right], \quad (4)$$

where k_e is a NEPOS cutoff wavenumber (a TNOS equivalent for "electron rest mass" m_e).

The Euler-Lagrange equation for free oscillations of a NOS is $\Lambda \vec{\mathfrak{N}} = 0$, where

$$\Lambda \vec{\mathfrak{N}} = \sum_\tau \frac{d}{d\tau} \left[\frac{\partial h}{\partial (\partial \vec{\mathfrak{N}} / \partial \tau)} \right] - \frac{\partial h}{\partial \vec{\mathfrak{N}}}, \quad (5)$$

τ is each of the spatio-temporal coordinates. Substituting (3) and (4) to (5), the wave equation $\nabla^2 \vec{\mathfrak{N}}^\gamma = 0$ for NEMOS wavefunction, as well as the Klein-Gordon equation $\nabla^2 \vec{\mathfrak{N}}^e + k_e^2 \vec{\mathfrak{N}}^e = 0$ for NEPOS wavefunction, can be obtained.

The momentum-energy is a dynamic value arising from the “movement” of 3D world over 4D spacetime in the temporal direction. Excited NOS eigenmodes “vibrate” like animated cartoon from the point of view of a 3D observer. The frequency of this vibration describes the eigenmode’s energy, while the quickness and the direction of spatial displacement of the oscillation’s phase define its momentum. In other words, momentum-energy is defined as flow of the action through 3D world. The momentum-energy four-vector of m -th eigenmode is

$$\vec{W}_m = K_m \eta \frac{k_m}{|\vec{k}_m|} \vec{k}_m,$$

where \vec{k}_m is the wavenumber of this eigenmode; $K_m = 0, 1, \dots$ is the occupation number [1].

Examples and Outcomes

Despite seeming triviality of considered TNOS hypotheses, their consistent application may result in unexpected outcomes. E.g., time-independent EM potential around rest “electron” does not contain energy; all electron self-energy must be a result of NEPOS oscillation. Another outcome is that the action dH of a “free rest electron” at a time interval dt is zero, not of $-m_e c dt$ [1]. The reason is that the action of a NOS free oscillation is identically equal to zero. One more outcome is the absence of so-called “zero-point oscillations” of vacuum (because the hypothetical value of eigenmode’s “zero-point energy” $\eta |\vec{k}_m| / 2$ does not satisfy the momentum-energy quantization principle). Only the zero-point oscillations of “composite” oscillators (like crystal lattices), based on the interaction between NEPOS and NEMOS, exist [5].

Let’s consider simple examples of NOS wave packets. A stationary fully nonlocalized NEPOS wave packet consisting of single eigenmode with $k_t = 20$ is shown in Fig. 1, a. The wavefunction components for this packet are: $\aleph_x^e = \cos k_t t$; $\aleph_t^e \equiv 0$. Black color designates the maximal value of \aleph_x^e component while white one indicates the one’s minimal value. This wave packet contains 20 positive and 20 negative action quanta. The negative quanta are generated by variation of \aleph_x^e in t direction, the positive ones are produced by the last term in (4). Such eigenmode is the free oscillation of NEPOS.

If a pair of positive and negative action quanta is generated by the stochastic mechanism, \aleph_x^e component takes one variation along x axis (Fig. 1, b) and one more positive action quantum. \aleph_t^y component of NEMOS wavefunction also obtains one variation along x (Fig. 1, c) and one negative action quantum. So, new NEPOS eigenmode contains 21 positive and 20 negative action quanta and is the forced oscillation. Excited NEMOS eigenmode contains one negative quantum and is also forced. NEMOS deviation in Fig. 1, c is positive at $x=0$. The reason is that the wave packet in Fig. 1, a has $k_t > 0$, i.e., this is “positron”. The “electron” with $k_t = -20$ after the interaction with NEMOS excites negative at $x=0$ NEMOS eigenmode (Fig. 1, d).

Generally, the wavefunction for a moving toward the x direction “electron” or “positron” localized wave packet is shown in Fig. 1, e. Fig. 1, f shows a spatial component of NEMOS wavefunction for spatio-temporally localized in t, x directions NEMOS wave packet (“photon”) moving backward the x axis. Unlike (4), (3) does not contain both real-valued and imaginary components of the NOS wavefunction in quadrature together, so, spectrum of EM action and momentum-energy is symmetric about zero. This corresponds with the Wheeler-Feynman’s concept of equal parts of “advanced” and “retarded” potentials in the EM interactions [2, 3].

Another corroboration of our hypothesis is the existence of electron waves in conductors and superconductors. Solid-state theory considers unbounded (conductivity) “electrons” in metal crystals as normal modes of “electron gas” rather than localized particles squeezing one’s way through atomic lattice. Why “electrons” in conductive media and “electrons” in vacuum exhibit different behavior? The reason is that all internal volume of the conductive or superconductive crystal is equipotential. High mobility of “electron gas” allows one effective smoothing

any inhomogeneities of EM potential. Therefore, there are no harmonics of $\vec{\mathfrak{N}}^{\gamma}$ differing from zero within a metal volume. If so, the described above mechanism of electron wave packet formation does not work for the “conductivity electrons”. Only separate NEPOS eigenmodes can exist in the conductive media, except for the bounded (valence band) “electrons”, which are essentially localized with strongly non-uniform EM potential of atomic nuclei.

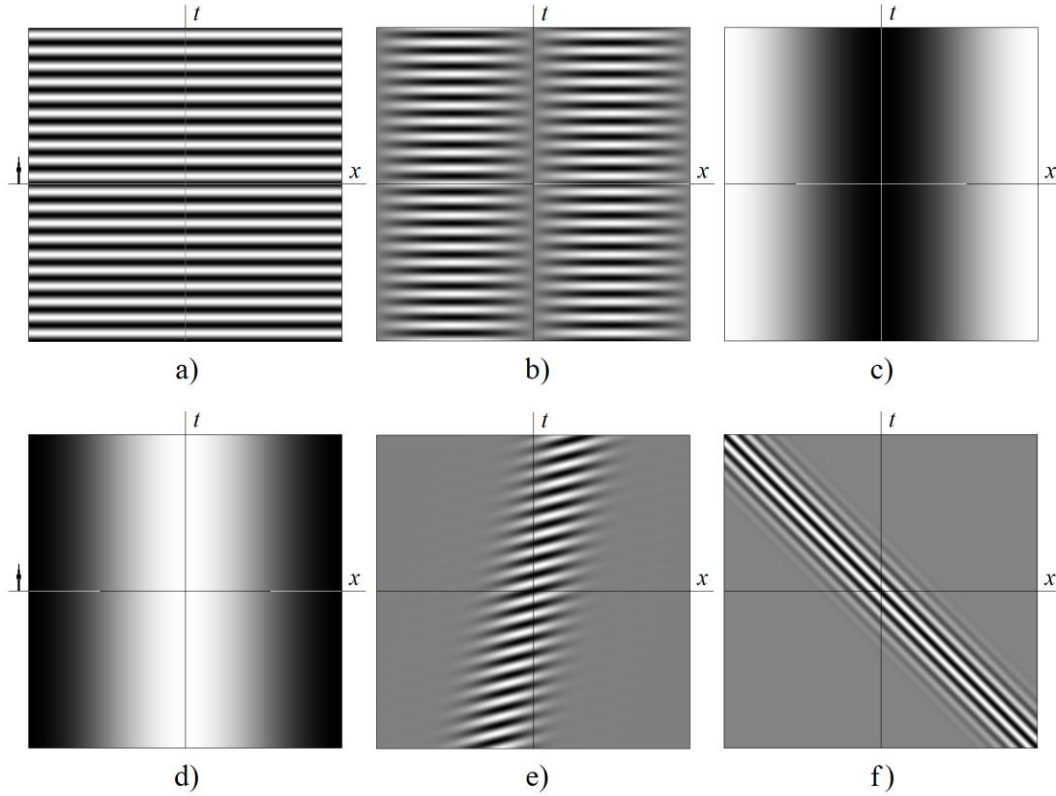


Fig. 1. 2D $(x-t)$ sections of the spacetime filled with NOS eigenmodes and wave packets

Conclusion

Spatially or spatio-temporally localized wave packets of natural distributed oscillatory systems may be considered as full-value equivalents of “elementary particles.” Such wave packets are composite dynamic objects; their existence is possible due to the permanent stochastic interaction between different oscillatory systems widening spectra of their oscillations and causing all oscillations to be forced, not free. The proposed concept describes some specific behavior of de Broglie waves in conductors and superconductors. The results may be useful for the development of new nanoelectronic components and quantum computers.

References

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