Deterministic interpretation of quantum mechanics

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The paper presents a polarization interpretation of quantum mechanics that gives a deterministic description of microsystems in the polarization world where particles are born. It does not have relativistic limitations on the matter velocity; therefore Bell’s inequalities are not applicable. Individual characteristics of particles in the polarization world represent their hidden parameters in transition to the relativistic world. The deterministic interpretation of quantum mechanics presented allows resolving its key conceptual problems: wave-corpuscle duality, particle trajectories, Schrödinger’s cat and Einstein-Podolsky-Rosen (EPR) paradoxes, selection of quantum system states during measurements. A derivation of the heuristically found Schrödinger equation is given for the first time.

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1. Introduction.

Quantum mechanics (QM) is usefully employed in many areas of physics, and yet the conceptual problems listed in the Abstract above, which had become apparent at the time of establishing QM, still cannot be considered solved. This stimulates further attempts to interpret QM. At present there are more than ten interpretations of QM [1-4], but none of them can resolve all its conceptual problems and reveal the nature of the wave field described by the Schrödinger equation. This is also true for the Copenhagen interpretation that is dominating today. Therefore V.L. Ginzburg included the QM interpretation problem with the three “great problems” of physics along with those of the time arrow and reducing the living matter to inert one [5].

The most complicated problem in QM is the measurement problem. The Copenhagen interpretation postulates state reduction during a measurement. This postulate was introduced to have agreement with experiment where one of alternative quantum system states is only observed at any time. However, the reduction (wave function collapse) is not described by the Schrödinger equation. This inconsistency of the theory gave an impetus to the search for other interpretations of QM. A measurement is now treated as an interaction of a system and a measuring instrument where superposition of states is still preserved though changes its form. And the system transition from the pure state to the mixed one is described by means of a decoherence mechanism [6, 7]. Decoherence originates from *entanglement* of the system with the environment (instrument) considered as a quantum macrosystem, which results in the loss of quantum correlation of states (decoherence) by the system, and realization of the mixed state during the measurement. The decoherence, however, does not solve the problem of alternative state selection that takes place during measurements. This stimulated the search for a selection mechanism, which cannot be considered completed yet.

As early as in 1957 H. Everett [8] proposed the “many-worlds” interpretation of QM that excludes the reduction. One of its statements is existence of multiple classical worlds (Everett worlds) corresponding to all possible alternatives. Every observer exists in each of the Everett worlds where one of alternative systems states is realized and is being observed.

Another formulation has been developing lately, where the researcher’s consciousness separates alternatives such that subjectively the researcher will only perceive one of the alternative classical views of the world [4]. With this approach there is no time arrow in the quantum world, it only occurs in the consciousness of an observer who perceives alternatives separately. The drawback of such an approach is that two poorly understood notions – separation of alternatives and consciousness – have to explain each other.

It can be acknowledged that the state selection problem cannot be considered solved; further search is required to find a QM interpretation that would remove all of the QM conceptual problems.

The paper introduces a new – polarization – interpretation of the QM which central tenets are presented in [9]. It reveals the information nature of the wave function as assumed, for example, in [10], and derives the Schrödinger equation from the information field equation found in [9]. Polarization mechanisms discussed in [9] will allow finding answers to a number of conceptual issues inherent in QM, including the measurement problem: how a transition from a pure state to the mixed one occurs, along with quantum state selection during measurements. Key points of the polarization theory (PT) [9] required for polarization interpretation of QM are listed below.

The PT underlying approach differs essentially from the modern fundamental physics concept and allows broadening its application area while using the minimum number of fundamental constants – light velocity *c*, Plank's constant *h* and gravitation constant *G*. This makes it impossible to generalize the PT that is claiming the status of a universal theory of "Everything" [9] and allows approaching the QM problems from the generic theory perspective.

For further discussion we will need a number of PT postulates and results cited below.

1. Nature is produced by polarization processes occurring in the zero vacuum where all physical quantities have zero values. Their non-zero values arise from polarization processes described by polarization conditions, the simplest of which take the following form:

$$a+b=0;\ \ \vec{a}+\vec{b}=0;\quad a^2+b^2=0. \tag{1}$$

The latter condition is responsible for polarization of imaginary physical quantities. In the general case all physical quantities are complex. It is assumed that imaginary components of scalar fields are information ones. The Schrödinger's wave field is one of them.

2. Matter does not originate in void, it comes into being together with its space-time (ST) thus forming the polarization world (PW). As in the case of all the other physical quantities, the ST coordinates are complex. Each of them acquires two physically different directions, which produces ST-states (STS) that differ at least in one direction of the ST coordinates. The number of STS for a $d-$dimensional complex ST equals

$$k_d=2^{(2^d)};\quad k_d{}^2=k_{d+1}. \tag{2}$$

Fields and particles are generated as part of polarization multiplets which dimensionality is defined by their symmetry in the PW. The value of k_d determines dimensionality of the ST-multiplet.

3. Three types of spatial symmetry produce three types of worlds. Translational symmetry produces a world of initial scalar wave fields that contains structures characterized by one or another field propagation velocity ($c-$worlds). In these structures, there emerge inclusions with axially symmetric space where scalar field oscillations may be polarized to produce oppositely directed vortex excitations characterized by the value of Plank's constant h. These inclusions represent $h-$universes where quantum fields and particles of non-gravitating matter are generated. Finally, centrally symmetric inclusions where gravitation arises emerge in *h*-universes. These are *G*-universes, one of which is our Universe that is characterized by known values of constants *c, h* and *G*. These worlds are investigated in [9]. The PT allows calculating constants of fundamental interactions, Weinberg and Cabibbo angles of the Standard model, determining spectrum and mass of fundamental particles (without introducing the hypothesis of existence of Higgs bosons).

4. As shown in [9], the ST of the polarization world is 11-dimensional. It includes three-dimensional spaces of the three worlds and two scalar coordinates – two times. One of them (τ) determines dynamics of polarization processes, and the other (*t*) – dynamics of generated

particles and fields. The latter time appears in the 4-dimensional Minkowski space of our relativistic world (RW). Nobody has observed particle birth and disappearance processes in the polarization world, which means that the PW is invisible to us and our instruments.

The Schrödinger's wave field is generated by the wave field of the five-dimensional *c*-world. Being an imaginary component of the scalar field, it differs qualitatively from the four fundamental fields known to us.

5. Claiming universality and developing a common approach to description of micro- and macroworlds, the PT cannot be based on indeterminism of the Copenhagen interpretation of QM, since phenomena not consistent with such indeterminism do exist in the macroworld. The best known of such phenomena is that of self-fulfilling prophecies. Hence the PT accepts the hypothesis of determinism in respect to events in macro- and microworlds, which calls, in particular, for deterministic interpretation of QM.

2. Particle trajectory problem.

The probabilistic interpretation of microparticle behavior is based on the notion that they do not have trajectories, which entails quantum-classical duality of the world since in the classical mechanics bodies have trajectories. Instead of an obvious question how then movement of micro-objects occurs, let us discuss to what extent this non-trivial conception is substantiated. It rests on (1) interferential experiments with particle beams that gave rise to the notion of corpuscular-wave duality, (2) Heisenberg uncertainty principle, and (3) principle of identity of particles of the same type. Are their other interpretations possible?

In QM particles of the same type are considered indistinguishable (identical). This implies that their trajectories are untrackable for us, but does not yet mean that particles do not have trajectories. Limitations of our measuring capabilities are not an augment for depriving particles, indistinguishable to us, of their trajectories*. The microworld existed and can well exist without an experimentalist. So whether particles can be considered identical, i.e. objectively the same, or they are different but indistinguishable for us?

QM describes behavior of particles that following their birth in the polarization world transit to the Minkowski space of the relativistic world. Some of the particle properties (charge, mass, spin, moment) define the state and behavior of the particles at such a transition. ST-states of particles and their associated internal structure are not taken into account in QM. This makes it possible to view particles as point objects, which simplifies investigations of their behavior but does not exclude existence of polarization processes invisible to us and influencing intrinsic and information properties and dynamics of quantum mechanics objects. The least action principle keeps a particle in the Minkowski space but does not take into consideration changes in the imaginary component of the action or processes occurring in the PW.

Quantum mechanics does not give a complete description of the behavior of particles of matter. The point nature of particles results in divergence of physical quantities in the quantum field theory (QFT). This is the price we have to pay for the simplified description of quantum matter. In QM the birth and destruction of "identical" particles is described by the secondary quantization method. The birth and destruction operators change the number of particles, and nothing more. The process of particle birth and destruction itself is not considered.

The PT rectifies this major drawback of QM: in this theory, no particle can appear in the Minkowski space unless inside the particle there emerges a structure that is associated with the PW and carries hidden properties of the particle along with information about its origination. Hence "point" divergencies of physical quantities are impossible in the PT, and there is no need for renormalizations, seed masses and charges, as well as other tricks aimed at achieving a better agreement between the quantum theory and experimental data.

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* Because it is one particle that leaves a trace in the bubble chamber.

Since ST-states are different for the same RW particles in the PW, it is unjustified to speak about their identity. The situation is similar to that of monozygotic twins: they are almost indistinguishable in appearance, but can be discerned by character and "life trajectory". In QM we abstract away from inner properties of particles, and they become indistinguishable to us. But this does not mean that because of this particles shall be deprived of their dynamic behavior and of such aspect as trajectory, and the world shall be considered to be indeterministic. For further consideration it is important to note that particles are produced by STS-multiplets, but today this difference between the particles' STS is disregarded.

The best known QM interpretations that include the notion of particle trajectories are those by D. Bohm and R. Feynman. The latter uses particle trajectory [$\vec{r}$] given by action $\Sigma\left([\vec{r}]\right)$ for building a wave function in the form of a so-called trajectory integral summing up weighted wave functions corresponding to possible trajectories starting in point r_1 and ending in point r_2:

$$\Psi(r_1, r_2) = \int_{r_1}^{r_2} e^{\frac{i\Sigma([\vec{r}])}{\hbar}} d[\vec{r}].$$

This idea is developed in the theory of combined quantum histories [2,11,12], where the total amplitude Ψ is represented by a superposition of amplitudes corresponding to different "quantum histories" conventionally reduced to a bundle of Feynman's trajectories.

D. Bohm [13] proposed a dual description of a particle, meaning that it has trajectory along with wave function. The trajectory statistics is described by the Schrödinger equation, hence predictions of the Bohm theory and conventional probabilistic interpretation of QM coincide.

With the polarization approach, all particles have trajectory, i.e. there is no quantum-classical duality.

3. Information nature of the Schrödinger's wave field.

Quantum mechanics does not provide a full description of the quantum world. It does not disclose the nature of the Schrödinger's wave field, its origin. The Schrödinger equation was found heuristically. Its wave function controls behavior of microparticles, but the interaction mechanism is not clear. The Schrödinger's wave Ψ-field does not fit our views of force fields and relativistic field quanta transferring interactions. No quanta of this scalar field have been discovered, and the field propagates differently than, say, the Klein-Focke-Gordon scalar field. Here we come up against an anomalous field. In the polarization theory its nature proves to be information [1].

The wave function has a polarization association with the particle for it is defined by its action $\Sigma : \Psi \sim e^{-i\Sigma/\hbar}$. This form of the wave function satisfies the Schrödinger equation since in mechanics $\frac{\partial \Sigma}{\partial t} = -E$ and, hence,

$$\hat{H}\,\Psi = i\hbar \frac{\partial \Psi}{\partial t} = E\Psi.$$

This equation defines quantum states of a particle with energy *E*.

In the relativistic world that we know, propagation of a free scalar field, i.e. the field that is not associated with particles it generated, is described by the wave equation

$$\frac{1}{c^2}\frac{\partial^2 \varphi}{\partial t^2} - \Delta\varphi = 0. \qquad (3)$$

In the polarization world, where the field produces particles, the field equation shall describe a coupled quantum system field--particle. Formation of a particle takes place in its individual space-time where time τ differs from time *t* that describes the field change. Generalization of a real free field for the system field --particle is a complex field localized in a complex space-time:

$$\chi = \tilde{\Phi}(\vec{r}, t, \tau') + i\tilde{\Psi}(\vec{r}', \tau', t) \qquad (4)$$

The prime mark indicates imaginary coordinates, with $\tau' = \pm\tau$. The time of the system field—particle is a complex quantity $\theta = t \pm i\tau$. To this time, there corresponds the following operator:

$$\hat{\xi} = \frac{\partial}{\partial t} \pm i \frac{\partial}{\partial \tau} \quad , \tag{5}$$

that satisfies the polarization condition for operators:

$$\hat{\xi}\theta = 0. \tag{6}$$

The complex scalar operator acting in the vector coordinate space is

$$\Delta \pm i\Delta' \equiv \frac{\partial^2}{\partial \vec{r}^{\,2}} \pm i \frac{\partial^2}{\partial \vec{r}'^{\,2}}$$

The sought scalar field χ is defined by the following operator

$$\hat{Q} = \frac{1}{c^2}\left(\frac{\partial}{\partial t} \pm i \frac{\partial}{\partial \tau}\right)^2 - \Delta \pm i\Delta', \tag{7}$$

that satisfies the polarization condition:

$$\hat{Q}\chi = 0. \tag{8}$$

When imaginary components disappear, operator (7) reduces to the operator of equation (3).

Using the polarization relation for spatial coordinates

$$\vec{r}^{\,2} + \vec{r}'^{\,2} = 0,$$

the spatial distribution of field $\tilde{\Psi}$ can be represented via coordinates of the real part of the space. Having separated real and imaginary components, we obtain the following two equations in the five-dimensional space-time from (8):

$$\left[\frac{1}{c^2}\left(\frac{\partial^2}{\partial \tau^2} - \frac{\partial^2}{\partial t^2} + \Delta\right)\right]\tilde{\Phi} = 0, \tag{9}$$

$$\left(\frac{2}{c^2}\frac{\partial^2}{\partial \tau \partial t} - \Delta\right)\tilde{\Psi} = 0. \tag{10}$$

These are sought-for equations of the scalar field being polarized together with the particle.

Quantum mechanics operates with polarized particles of mass m in the 4-dimensional space ($\vec{r}, t$). Transition to this space takes place at polarization of the action $\pm mc^2\tau$ between the particle and the quantum system field:

$$\tilde{\Phi} = e^{\pm\frac{imc^2\tau}{\hbar}}\Phi(\vec{r},t); \tilde{\Psi} = e^{\pm\frac{imc^2\tau}{\hbar}}\Psi(\vec{r},t). \tag{11}$$

Since $\tilde{\Phi}$ and $\tilde{\Psi}$ are real values, fields $\Phi(\vec{r},t)$ and $\Psi(\vec{r},t)$ are complex. From (9-11) it follows that they satisfy respectively the Klein-Focke-Gordon equation

$$\left[\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \Delta + \left(\frac{mc}{\hbar}\right)^2\right]\Phi = 0 \tag{12}$$

and Schrödinger equation

$$i\hbar\frac{\partial \Psi}{\partial t} = \hat{H}\Psi; \quad \hat{H} = \frac{\hat{p}^2}{2m}. \tag{13}$$

This ascertains the polarization origin of these fields demonstrating the association between the quantum field theory and quantum mechanics.

Formation of particles and their further residence in the polarization world take place at constant velocity in the state of unstable equilibrium of the system. At a force action on a particle upsetting the equilibrium, the particle passes into the relativistic world where Hamiltonian $\hat{H}$ includes the acting force potential.

Equation (12) represents an operator analog of the relativistic polarization relation for free particles $E^2=p^2c^2+m^2c^4$. It is considered that the Schrödinger equation $\hat{H}=\frac{\hat{p}^2}{2m}$ describes non-relativistic motion of matter, while the wave function $\Psi(\vec{r},t)$ is useless in relativistic limit. However, the non-relativistic limit was not applied when deriving the equation with the polarization approach (otherwise the relativistically invariant equation for the field Φ could not be obtained). The non-relativistic form of the kinetic energy operator in the Schrödinger equation cannot be indicative of its any relativistic limitations since the field Ψ is localized in the imaginary subspace, while the special theory of relativity applies to the real one.

The Schrödinger's wave field Ψ is *information* in nature. That is why its manifestations in the real subspace are so unusual. The information field $\tilde{\Psi}$ initiates formation of particles and defines their density. The imaginary field $i\Psi$ makes the Universe a single information-bound structure. The non-locality of field Ψ was mentioned in [14] when describing its property of instantaneous binding of "all parts of the entire world".

Interference experiments show that the wave function influences particle fluxes. What kind of mechanism is possible here?

As is demonstrated by the Schrödinger equation (13), particles are born in a free state, for example, a particle flux is a polarization world system. In a flow of particles of the same type, their density n satisfies the continuity equation

$$\frac{\partial n}{\partial t}+\mathrm{div}n\vec{\mathrm{v}}=0\,. \tag{14}$$

Let us show that for a system comprised of numerous identical particles their density $n\sim|\Psi|^2$. At a transition to the relativistic world the wave field $\tilde{\Psi}$ changes its phase to $\Sigma/\hbar$, where Σ is the action of field polarizing along with the particle action:

$$\Psi=e^{i\frac{\Sigma}{\hbar}}\tilde{\Psi}\,. \tag{15}$$

Substituting (15) into the Schrödinger equation with potential energy U and separately setting to zero its real and imaginary parts, we arrive at the following two know equations:

$$\begin{aligned}&\frac{\partial\Sigma}{\partial t}+\frac{1}{2m}(\vec{\nabla}\Sigma)^2+U-\frac{\hbar^2\Delta\tilde{\Psi}}{2m\tilde{\Psi}}=0\\&\frac{\partial\tilde{\Psi}}{\partial t}+\frac{\tilde{\Psi}}{2m}\Delta\Sigma+\frac{1}{m}\vec{\nabla}\Sigma\cdot\vec{\nabla}\tilde{\Psi}=0\end{aligned} \tag{16}$$

The first one in limit $\hbar^2\to 0$ transforms into the classical Hamilton-Jacobi equation for particle action Σ, i.e. classical mechanics is true to the first order of magnitude for $\hbar$. The second equation (16) in the form

$$\frac{\partial\tilde{\Psi}}{\partial t}+\mathrm{div}\left(\frac{\vec{\nabla}\Sigma}{m}\tilde{\Psi}\right)=0 \tag{17}$$

is nothing else but the continuity equation for $\tilde{\Psi}^2=|\Psi|^2$ since $\frac{\vec{\nabla}\Sigma}{m}$ is the particle velocity. If the number of quantum particles is sufficiently large to allow using the concept of continuum, its density n and mean velocity $\vec{\mathrm{v}}$ related by (14), then from (17) we obtain

$$\frac{d\ln|\Psi|^2}{dt} = -\text{div}\ \vec{\text{v}} = \frac{d\ln n}{dt} \quad \text{and} \quad n \sim |\Psi|^2 = \tilde{\Psi}^2. \qquad (18)$$

This is a known quantum mechanics relationship. A new development in it is that the particle density is defined by the field $\tilde{\Psi}$ of the five-dimensional ST.

The phase factor in (15) has no effect on the particle density but is essential for behavior of an individual particle since it defines the wavelength $\lambda\!\!\!^{-} = \dfrac{\hbar}{m\text{v}}$ of the field that correlates with the particle. It is believed that the de Broglie wave characterizes the wave aspect of a particle, and its "wave scale" $\lambda\!\!\!^{-}$ defines the particle collision cross-sections that are much larger than their own cross-sections. But if a particle is just a corpuscle, another explanation is required. The similar situation is with interference experiments that produced the concept of the corpuscular-wave duality.

4. About corpuscular-wave duality.

With the polarization approach particles are corpuscles, hence wave manifestations in experiments with microparticles should be interpreted in terms of dynamics. There should be distinguished two cases of interaction between particles when the particles are localized either in the same wave of the field or in different waves. In the first case we deal with collision of particles, while the second case is the interference experiment, hence action polarization methods are different. In case of collision the action occurs between particles, and in interference experiments – between a particle and a field.

The substance of interference experiments with an electron beam is that when there are two slits in the screen, the pattern obtained on the electron receiver surface in case of simultaneously open slits differs from that when the slits are open at different times. In the latter case a combination of diffraction patterns from different slits is observed, while in the former one a pattern similar to optical interference is produced. While there are few particles that have reached the receiver, nothing resembles the interference pattern, i.e. the wave field does not influence dynamics of individual particles but affects their sufficiently large array*. In 1947 V.A. Fabrikant set an experiment where electrons reached the target one at a time: the interval between emissions was four orders of magnitude greater than the flight time to the target, however, the interference pattern took place.

When there are two slits in the screen, the wave function behind the screen is a superposition of wave functions being formed in the slits. This results in interference of the wave fields similar to the optical interference. According to (18), the density of particles on the receiver surface will be defined by the interference pattern, with a fairly large number of electrons required for it to be implemented. And single-electron motion dynamics is not defined by the wave function. Therefore it is necessary to identify a force that makes electrons change their direction in the slits and transforms the homogeneous beam into the heterogeneous one. It is shown in [9] that pairs of neutral scalar particles and negaparticles are born in the PW. The change in their mass during their generation produces reactive thrust $\dfrac{dm}{d\tau}\text{v}$ that can turn a velocity vector of an electron with mass m_e in the slit by angle $\alpha(t)$ defined by the following equation:

$$m_e r\ddot{\alpha} = -\left|\frac{dm}{d\tau}\right| r\dot{\alpha} \qquad (19)$$

* The uncertainty relation is derived for the particle array rather than for an individual particle, which thus does not prohibit the particle from having a trajectory.

The turning radius r has no effect on α, i.e. the turn of the trajectory is possible in a slit of any width. Considering that $\alpha(t=0)=0$, we obtain from (19)

$$\alpha = \alpha_0 \left(1 - e^{-\left|\frac{dm}{d\tau}\right| \frac{t}{m_e}} \right) \tag{20}$$

The integration constant α_0 defines the rotation angle and allows bringing the particle trajectory into agreement with the interfering scalar field.

Thus the corpuscular-wave duality is not the only possible interpretation of the considered experiments. They can also be explained within the framework of the polarization paradigm that treats particles as corpuscles only.

We cannot observe wave properties of the imaginary field $i\Psi$ localized in the imaginary subspace. Instead of this, we see a distribution of particles that correlates with the field and mistakenly decide that they also have a wave nature. This peculiarity of the field Ψ manifests itself in the operator representation of the physical quantity and commutation relations. The polarization correlation between particle multiplets and field allows determining the mean value of physical quantity $<f>$ over the particle ensemble through the field:

$$< f >= \int \Psi^* \hat{f} \Psi dq$$

The QM formalism is a technique of averaging physical quantities of particle systems having a polarization association with the field Ψ. It should not be considered as reflection of the wave nature of microparticles.

5. EPR-pair correlation mechanism.

The thought experiment by Einstein, Podolsky and Rosen (EPR-paradox) [14] was made in order to differentiate between two possible interpretations of QM. The Einstein's statistical interpretation of the wave function gives a probabilistic description of an ensemble of the same microsystems, i.e. conclusions of the QM cannot be applied to individual microsystems. The Copenhagen interpretation assumes that the wave function gives a probabilistic description of an individual microsystem which cannot be deterministic, and suggests that a microsystem has no trajectory. These two approaches cannot be distinguished experimentally since probabilistic predictions can only be checked by processing a set of experiments [15].

In the Einstein's interpretation the description of QM is incomplete, i.e. there may exist unobservable variables (hidden parameters) that allow obtaining a more detailed description of the matter. At a deeper fundamental level its deterministic description is possible, which, after averaging over hidden parameters, will pass to the quantum one. In this theory, average values of physical quantities shall coincide with quantum averages [15]. Schrödinger, de Broglie, Bohm and a number of other prominent physical scientists expressed a desire of having a deterministic theory of microphenomena that would encompass the QM.

Analyzing this dilemma, in 1964 J. Bell arrived at a conclusion about a non-local nature of theories with hidden parameters [16]: theories with hidden parameters that reproduce all QM results should be non-local, i.e. measurements performed in one point should influence measurements in another point. Inequalities he obtained hold for any statistical system where signal cannot propagate at superluminal speed.

Numerous experiments performed with EPR-pairs of photons and protons have demonstrated that the Bell's inequalities are violated. This is treated as confirmation of the Copenhagen interpretation of QM since the former postulates that each particle is found simultaneously in all space points where the wave function is nonzero. According to [17], the reason for violation of the Bell's inequalities is that measurement of one of the particles leading to a collapse of the wave function changes information about the system thus influencing probability of detecting another particle.

However, the Copenhagen interpretation of QM does not satisfy many of the physical scientists since it does not answer a number of principle issues. In particular, the following two paradoxes are associated with it: (1) behavior of an individual object is unpredictable, but QM can describe behavior of an ensemble of such objects to any degree of accuracy, and (2) it appears that an outcome of an individual event, i.e. an event that has no cause can be predicted in correlation EPR-experiments (in the limit with a hundred percent probability) [18].

The major challenge for the deterministic interpretation of QM is to explain which physical mechanism is responsible for the Bell's non-locality where there are hidden parameters, and what kind of parameters are these. Assumptions about existence of instantaneous interactions of force or forceless type that are distance independent are still speculations. No satisfactory mechanism of EPR-pair correlation has been found so far.

Does the PT cast light upon this problem?

EPR-pairs of photons and massive particles have a polarization origin: they are produced with a zero total impulse and fly in opposite directions. As noted in the Introduction above, in the PT particles are generated as ST-multiplets: every their particle in the PW has its own ST-state that differs in direction (sign) of at least one of the ST-coordinates. In case of EPR pair particles, their STS differ in direction of one of the spatial coordinates along which the particles fly apart. In the quantum theory of RW they play a role of hidden parameters since coordinate directions are not polarized there. STS individualize a state of the same particles, which is a necessary condition for their deterministic description. Since particles of an EPR-pair are found in different PW spaces, they cannot interact through any field (force or forceless) because no field can be localized concurrently in the both spaces. As no relativistic limitations on particle and field velocities exist in the PW, the Bell's inequalities are not applicable, and their violation does not testify contrarily to the Einstein's interpretation of QM and possibility to have deterministic description of matter. The polarization interpretation of QM, in essence, represents concretization of the Einstein's concept.

What is a possible non-local mechanism of correlation of EPR-pairs in the PT?

An EPR-pair is an equilibrium system with respect to polarization where the following initial parameters are maintained at a free fly-off of the particles: impulse, energy, spin and charge of the particles. For the zero action of the pair flying apart to be retained, its wave function should be expressed as a product of wave functions of its particles that are proportional to $e^{\frac{i\Sigma_{1,2}}{\hbar}}$, where $\Sigma_{1,2}(t)$ are actions of particles 1 and 2 that satisfy the polarization condition $\Sigma_1 + \Sigma_2 = 0$. For example, for a proton or electron pair we have

$$\psi = 2^{-1/2}[\chi_1(-1/2)\varphi_1(1/2) - \chi_2(1/2)\varphi_2(-1/2)], \qquad (21)$$

where projections of spins of particles 1 and 2 on the selected direction are shown in brackets. Such a wave function characterizes, according to the current terminology, entangled particles of an EPR-pair. Their entanglement results from polarization equilibrium.

A disturbance of polarization equilibrium of the pair in some point of the PW produces a force that compensates for the disturbance and is distance independent. This polarization reactive force was discussed in the previous section. In particular, it results in keeping color-charged quarks inside adrons which volume represents PW inclusions in the RW where free quarks cannot exist. In these inclusions, color charges have a zero sum, i.e. they represent polarization formed systems. When the adron form deviates from the equilibrium one, distance independent polarization reactive forces keep quarks from flying apart. This confinement mechanism was checked on mesons, and a good quantitative agreement between the retention force potential and its experimental values was obtained [9, 19].

Measurements in EPR-experiments are made in the RW where an EPR-pair passes as a single object being in a polarization equilibrium: the zero action of the pair does not lead to interaction between PW and RW where the equilibrium is upset due to interaction with the instrument. When taking the measurements, correlated particles of the pair find themselves in the

RW at the same time regardless of the distance between them. This makes it possible in principle to establish the fact of synchronous correlation. N. Gisin with his colleagues [20] have found that if the existence of interaction implementing correlation of photon EPR-pairs is assumed, the interaction propagation velocity will be higher than the light velocity by at least four orders of magnitude. No such interaction can occur in the PT, and the correlation mechanism consists in maintenance of the polarization equilibrium.

Thus, the PT allows concretizing the correlation mechanism in EPR-experiments without contradicting the deterministic interpretation of QM. The same mechanism implements known conservation laws in the RW.

6. “Schrödinger’s cat" paradox.

As is known, a quantum mechanics system is described by a superposition of its states with weighting factors. This is interpreted as simultaneous occurrence of these states with corresponding probability. If, for example, a point particle may be found in one of two points, its location “in two points at the same time” is also possible.* No such a situation is possible in classical mechanics, since a macroscopic system can only be in one of possible states. Their superposition does not have any physical meaning.

If we take it that an “amplification” mechanism transforming superposition of microstates into that of macrostates is possible during a measurement [4], we come up against a contradiction known as the “Schrödinger’s cat" paradox. Schrödinger illustrated it by a thought experiment. A cat is placed in a box along with a metastable atom and a Geiger counter. The same box contains a flask with poison and a device that can break the flask and poison the cat. When the atom decays, the counter activates the device, and the poison kills the cat. In the half-decay period the atom represents a superposition of decayed and non-decayed atom, i.e. the cat shall represent a superposition of alive and dead cat during that period. But as we know a cat can be either alive or dead.

It is assumed, for example in [4], that such “amplification” occurs at any measurement of a quantum system and consists in formation of an entangled state involving a macroscopic quantity of subsystems. To what extent this assumption is true? Can a macrosystem be viewed as a superposition of its quantum subsystems?

An attempt to resolve this paradox proposed by Heisenberg and developed further in recent years is based on the notion of “decoherence” [10,21]. It is believed that decoherence of a quantum system takes place every time its state is entangled with the state of the surrounding environment, resulting in transmission of information about the system state to the environment allowing the state superposition components to be distinguished. “This means that it becomes a mixture, rather than superposition, of the same components, and no experiments made with the system but not affecting the environment that causes decoherence can bring to light whether the mixture is due to the previous superposition or it results from incomplete knowledge as to which of the components really exists. Due to decoherence, quantum theory predictions for macroscopic states cannot be distinguished from predictions of the macrorealistic theory, unless literally all degrees of freedom are controlled” [4].

With the polarization approach the paradox can be resolved differently. Macrosystems (except for non-dissipative ones) cannot be treated as pure states since polarization interaction may occur between their particles born in the same STS, resulting in their entanglement and generation of uncorrelated macroscopic subsystems differing in their STS. Their number in the Minkowski space is defined by the stochastically significant value $k \approx 10^5$. Thus “amplification” of correlation between particles in macrosystems proves to be limited leading to formation of a mixed state in the latter. This makes classical systems different from quantum ones.

***** The possibility to move atoms inside molecules that currently exists is sufficient to reject this treatment.

7. Problem of measurements in QM.

The measurement problem is the most difficult of conceptual QM problems since attempts to solve it within the framework of QM have been failing so far. Hence various modifications of QM are proposed. One of them is the hypothesis of spontaneous decoherence [22] where a stochastic term describing this decoherence is included in the Schrödinger equation. In this case decoherence is not associated with the surrounding environment and occurs spontaneously without external influence. Since the first years of QM existence, hypotheses have been brought forward that it is necessary to include in it an observer [23] or his consciousness that may influence even reality [24, 25]. As noted in the Introduction above, the role of consciousness in QM interpretation has been rather extensively discussed of late (see References section in [4]) in spite of the fact that the consciousness phenomenon is not understood. Two most important issues in the measurement problem are: (1) how a pure state of a quantum system transforms into a mixed one, and (2) how selection of system quantum states observed in experiments takes place. The polarization approach offers new opportunities to find answers.

Let us assume that interaction between a quantum system and an instrument (macrosystem) is polarization one. For the sake of simplicity we will consider superposition of two quantum states

$$\Psi = c_1\psi_1 + c_2\psi_2 , \tag{22}$$

where ψ_1 and ψ_2 are wave functions of these states. The microsystem Ψ interacts with the instrument.

Let us follow [4] in description of the measurement process. At the initial state of instrument A the measurement result is defined by the state of microsystem Ψ. Their interaction that results in differentiation of states ψ_1 and ψ_2 (and does not change them) should only be considered. Differentiation of states means that final states of instrument A, corresponding to states ψ_1 and ψ_2, are different. The measurement can be represented as the following processes:

$$\psi_1 A \to \psi_1 A_1, \quad \psi_2 A \to \psi_2 A_2 .$$

The initial state (22) will cause transition

$$\Psi A \to c_1\psi_1 A_1 + c_2\psi_2 A_2 , \tag{23}$$

i.e. occurrence of the entangled state that we will designate as χ. This points to the polarization nature of the interaction under consideration. For example, if Ψ is a wave function of a zero-spin electron system, then ψ_1 and ψ_2 are wave functions of states of electrons with oppositely directed spins. States with a wave function A_1 and A_2 shall also have spin projections differing by 1. Thus when superposition (22) interacts with the instrument the former changes to the entangled state (23). This state is pure and can be described by the density matrix

$$M = |\chi|^2 . \tag{24}$$

Since we are only interested in states of system Ψ, this state can be described by a so-called reduced density matrix that equals the trace of matrix M for the instrument states (see, for example, [4]):

$$\rho = tr_A M = |c_1|^2|\psi_1|^2 + |c_2|^2|\psi_2|^2 + c_1c_2^* A_1A_2^*\psi_1\psi_2^* + c_2c_1^* A_2A_1^*\psi_2\psi_1^* . \tag{25}$$

When going to the mixed state the two last terms in (25) shall disappear.

In case of decoherence by the surrounding environment, the value of interference terms reduces with increasing number of degrees of freedom in the environment that are involved in the quantum system entanglement, so at a sufficiently large number of degrees of freedom such terms become small quantities, and pure state (23) tends to the mixed one [4].

In the case of the polarization approach, instrument wave functions A_1 and A_2 represent a sum of a large number (of order k_4) of phase-uncorrelated wave functions of its subsystems, i.e. these sums are not superpositions. We deal with a stochastic system where the set of all interference terms is small, and a mixed state is realized.

Let us consider a possible mechanism of measuring a quantum system with a large number of states. Instead of (23), we will have the wave function

$$\chi = \sum_i c_i A_i \psi_i \qquad (26)$$

We will describe the measurement process by the density matrix (24) representing a sum of quadratic terms $|c_i|^2 |\psi_i|^2 |A_i|^2$ and interference terms $c_i c_j^* A_j^* A_i \psi_j^* \psi_i$, where i and j are the state numbers.

In the foregoing we already presented the classical system (instrument) as an uncorrelated state of its quantum subsystems being in different STS. Let us now discuss physics of occurrence of quantum states superposition. In the PW, alternative states with wave functions ψ_i originate in different STS producing a multiplet of orthogonal states. It is impossible for a quantum system to be in different STS, and hence in alternative ψ_i states, at a time.

Superposition of alternative states occurs at a transition to the Minkowski space, where information about the quantum system STS is lost. In this case each state ψ_i has weight c_i that characterizes the frequency of its occurrence in the PW. Unlike the instrument, states of the quantum system that make up the polarization STS-multiplet, are correlated.

Let us now consider a polarization interaction between a multiplet of quantum states and an instrument. It may take place for their subsystems having common ST-states, i.e. between ψ_i and A_i (i is the subscript of STS) that produce entangled state $\psi_i A_i$.

Let polarization of action $\pm\Sigma = \pm(\Sigma_1 \pm i\Sigma_2)$ occur between ψ_i and A_i. This leads to a change in the amplitudes of these wave functions by a factor $\exp(\pm\Sigma_2/\hbar)$. Obviously, the polarization interaction being considered does not change $A_i\psi_i$ in (26) and thus quadratic and interference terms of matrix (24). The latter remain stochastically small. It is natural to assume that the instrument responds to this interaction when A_i grows exponentially. Thus there is a unique correspondence between the quantum system state ψ_i and instrument subsystem A_i, caused by the common STS. This means that the considered polarization mechanism implements selection of alternative states. Since the action polarization probability is the same in different STS, i.e. $|A_i|^2 = const$, the quadratic terms of matrix (24) $|c_i|^2 |\psi_i|^2 |A_i|^2$ are proportional to $|c_i|^2 |\psi_i|^2$. In view of the smallness of interference terms in (24), it is the mixed state that is measured.

Thus the considered polarization mechanism of interaction transfers the pure state (26) to the mixed one, with the instrument responding to one state of the quantum system in each measurement, and a unique correlation taking place between the quantum state of the system being measured and the instrument. This corresponds to peculiarities of quantum system measurements, i.e. the PT contains mechanisms that allow describing the physics of the measurement process in QM while staying within the latter.

8. Conclusion.

The polarization theory notion of existence of the invisible polarization world where particles and fields are born allows considering a number of conceptual problems of the QM, which still remain unresolved, on the basis of a unified perspective.

The heuristically found Schrödinger equation was for the first time derived within the framework of the polarization interpretation of QM by means of projection of the imaginary component of the scalar field localized in the five-dimensional ST to the four-dimensional world known to us. It follows that the Schrödinger's wave field has information nature. Projection of the real component of this field gives the Klein-Focke-Gordon equation for scalar particles. The wave field influences dynamics of its associated particles via reactive thrust produced when the scalar particle mass is formed. Examples of such correlation are interference of particles passing through screen slits, and particles of EPR-pairs which birth has a polarization nature. Hence the pair particles prove to be correlated at any distances.

The existing probabilistic (indeterministic) concept of QM is unacceptable for the universal polarization theory describing micro- and macro-objects in the common context, because phenomena contradicting the former approach do exist in the macroworld. The hypotheses about corpuscular-wave duality, identity of particles of the same type, and the absence of their trajectories are also unacceptable. The PT removes the halo of mysterious peculiarity of microparticles and uses concepts applicable to description of macro-objects.

Violation of the Bell's inequalities in the EPR-experiments is not an argument in favor of the Copenhagen interpretation of QM, because they cannot be applied in the PW where relativistic limitations on the matter velocity do not exist. In the PW, particles are characterized by their ST-states defining their quantum states and representing hidden parameters for the RW. Recently the authors of [26] provided arguments in favor of treatment of quantum states as physically distinct states of reality. The polarization interpretation of QM is refinement of the Einstein's interpretation of the wave function, and distance independent correlations of particles in EPR pairs are due to the mechanism of maintaining the polarization equilibrium by means of polarization reactive forces

Problems of measuring quantum microsystems are particularly difficult due to transfer of the pure state before the measurement to the mixed one after that, and selection of just one microsystem state by the instrument. An answer to the first question is being sought now on the assumption of "amplification" of superposition at interaction with the surrounding environment. Formation of entangled states of the microsystem and surrounding environment is considered as the amplification mechanism. These are pure states, and the decoherence theory is applied for transfer to the observed mixed state. According to this theory, each act of entanglement is accompanied by transmission of information to the surrounding environment, thus producing a mixed state. However, the state selection phenomenon cannot be explained by decoherence.

With the polarization approach the measurement problems are solved in a different way. A classical instrument represents a totality of uncorrelated quantum subsystems differing in their space-time states (STS) which number is equal to $\approx 10^5$. An interaction between the microsystem and the stochastic system of instrument states results in disappearance of interference terms of the density matrix and formation of a mixed state. To explain the microsystem state selection phenomenon it is assumed that polarization of complex action takes place between the quantum system state and the instrument subsystem that have a common STS and thus are uniquely correlated, resulting in the instrument response due to exponential growth of the amplitude of the instrument subsystem wave function.

The polarization interpretation of QM presented in this paper provides a unified approach to solution of conceptual problems inherent in QM while staying within its framework.

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