The concept of a field as the basis for the model of a quantum object

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Abstract

The model of a quantum object, based on the conception of a field, is presented in this research work. The way suggested allows to construct the model of a quantum object, which owns wave and particle properties simultaneously. The model is developed for the non-relativistic case and applied to three canonical experiments of quantum mechanics. This model describes successfully physical processes, happening at the quantum level, in these experiments. The analysis of some consequences of this model for the relativistic case is made. This model of a quantum object can be verified experimentally and a corresponding experiment is suggested for this goal.

1 Introduction

The developing of quantum field theory (QFT) faces with such issues as an impossibility to treat infinities calculating a gravity interaction. That urges physicists to search alternative theories. The vivid example of such theory is string theory [1]. In other cases in QFT renormalization allows to treat infinities which appear in calculations of physical processes. But at the same time renormalization demands to imply a charge of electron infinite for example.

The author of this work supposes that the source of the problems arising in QFT is the lack of “a working model of a quantum object” in quantum mechanics. By the working model of a quantum object the author means the following, quantum mechanics is a phenomenological theory. The adding of the working model of a quantum object in quantum mechanics allows us to describe processes which occur in quantum world. In its turn that should help to solve the problems QFT faces. This aim is connected with the problem of quantum mechanics interpretation. The review of the problem of quantum mechanics interpretation is given in [2].

The aim of this work is to suggest the working model of a quantum object.

2 The non-relativistic case

This model is constructed like a row of postulates and consequences from them. Let us consider the non-relativistic case.

Postulate 1. *A quantum object and its wave function are parts of a more compound object. This object exists at every point of space-time continuum. Later on, we shall name this object "field of matter" or short "m-field". A quantum object is a manifestation of a m-field.*

Postulate 2. *Every manifestation of a m-field as a quantum object is this quantum object in one of definite states, allowed by the wave function of this m-field. In a definite state every physical quantity of a quantum object (coordinates, momentum, energy, spin, etc.) takes one of corresponding operator eigenvalues. A probability of a physical quantity takes one of eigenvalues is subject to the laws of quantum mechanics. A choice of a concrete definite state of a quantum object from all possible ones, in which the m-field manifests itself, can not be ruled. This process has a random nature.*

A necessity of two following postulates springs logically from the first and second postulates. Evidently a quantum object evolves in time. Taking this and two first postulates into account we come to a conclusion that manifestations of a m-field change each other in the course of time. It brings us to the third postulate.

Postulate 3. *There is a tiny and fixed time interval* Δt*. Every time when* Δt *interval expires the following manifestation of a m-field changes the previous one. This time interval is the same for all m-fields. A following manifestation changes a previous one at one and the same time instant for all m-fields.*

Later on we show why Δt must be a finite time interval.

To fully describe a quantum world we have to introduce the four fundamental interactions between m-fields. In QFT force carriers are particles, but we already have an object which exists at every point of space-time continuum, this is a m-field. It is reasonable to entrust a function of force carriers to this object rely on Occam's razor principal.

Postulate 4. *A manifestation of a m-field consists of a quantum particle and corresponding to this quantum particle fundamental fields at every point of space-time continuum. A state of fundamental fields refreshes with every new manifestation of the m-field.*

Below everywhere we do not discuss photons emission by atoms and an interaction between light and atoms in this work, except the cases it is specially stipulated.

Consequence 1. We do not know the exact nature of an object which is the manifestation of a m-field, we can only judge it indirectly from experimental data. Therefore, in this model quantum particles are just objects with the set of parameters. Interaction of quantum objects depends on their parameters, but these parameters are not sure to correspond to some physical processes. For instance, existence of a spin does not mean automatically that a particle revolves around any axis in space. The spin of a quantum object can be just a parameter of an interaction.

Actually we do not even know exactly dimensions and forms of m-fields manifestations. We can only judge about it from experimental data. So it is reasonable to interpret the mass, the charge, the spin and other properties of a quantum particle as the parameters of a m-fields interaction, until experimental data point out the other way of things.

Consequence 2. In accordance with the first and second postulates a manifestation of a m-field is a quantum object in a definite state. The third postulate says that every manifestation of a m-field as the quantum object in the definite state exists during the time interval Δt. Hence m-fields interact with each other by means of quantum objects in definite states and by means of fundamental fields accordingly the fourth postulate.

Consequence 3. According to the first, second, and third postulates a changing spatial position by a quantum particle can be described in the following way, the wave function of the particle evolves by the Schrödinger equation. In every instant the wave function (except cases it is specially stipulated it is meant the squared modulus of a wave function) gives the set of points in space where the probability of the manifestation of a m-field is non-zero. At a certain time instant the m-field manifests itself as the quantum particle in a definite state. Hence the manifestation of the m-field occurs at the one of the above mentioned points in space. The probability of the manifestation of the m-field at some point is the probability which the wave function gives for this point in space. The third postulate says that the quantum particle exists at this point during the time interval Δt. When the time interval Δt elapses a new manifestation of the m-field happens.

Hereby changing spatial position by the quantum particle happens in the following way - the quantum particle appears in a instant t at a point in space A. Further the quantum particle stays at the point A for the time interval Δt, after that it appears at a point B. It takes the time interval Δt from the quantum particle to stay at the point B, then the quantum particle appears at the third point C etc. But the quantum particle does not move from one of these points to another.

Consequence 4. It follows from consequence number 3 that such notion of classical physics as “trajectory” can not be applied to the process of changing spatial position by a particle. Also we have to refuse from the classical concept of “motion” regarding particles. It is obvious that in this model the notion of “inertial frame of reference” becomes pointless to the process of changing spatial position by a particle.

Consequence 5. As it follows from the above the process which happens with a m-field can be described as the process at two levels. The first level of a m-field is its wave function and the evolution of this wave function by the Schrödinger equation. The second level of a m-field is its manifestations. The second level includes the manifestations of a m-field as the quantum object in definite states and the manifestations of a m-field as the fundamental fields corresponding to this quantum object.

For clarity’s sake the first postulate implies that a wave function is an element of reality in this model.

Consequence 6. As it follows from the second postulate a manifestation of a m-field is subject to the laws of quantum mechanics. Hence external fundamental fields influence only the wave function of the given particle by the Schrödinger equation. That means external fundamental fields do not influence directly the manifestation of the m-field i.e. the quantum particle. Otherwise the behaviour of the quantum particle would not be described by the Schrödinger equation. Hereby, it does not matter for the influence of external fundamental fields on a m-field at what point of space a manifestation of the m-field as a quantum particle occurs.

Taking into account consequence number 5 this deduction can be stated in the other way - the influence of external fundamental fields on a quantum object carries out only at the first level of a m-field.

From the above mentioned, it follows that the influence on a m-field of other m-fields can be divided into two types. The first type is the influence of external fundamental fields. This type of influence is described by the Schrödinger equation. The second type when an influence on a manifestation of a m-field as a quantum particle is exerted by a manifestation of another m-field as a quantum particle, i.e. quantum particles interact directly between each other. The Schrödinger equation does not describe this type of influence as quantum particles interact directly between each other without participation of four fundamental forces. These are such processes like absorption of particles, annihilation of particles with each other and collision of particles (if particles do not interact with each other by means of fundamental forces or this interaction can be neglected or the interaction of quantum particles by means of fundamental forces leads to their collision directly). The example of such processes is a collision of an electron and photon, it happens without an interaction of these particles by means of fundamental forces. An electron and photon collide directly with each other. Another example - an annihilation of an electron and positron, for annihilation an electron and positron collide with each other directly.

Hereby, the row of processes in quantum world happens at the second level of m-fields, consequently, it demands the manifestations of m-fields which take part in these processes. Later on, we shall name such processes as an interaction at the second level of m-fields.

Consequence 7. In conformity with consequences number 2 and number 6 actions of interaction between m-fields at the second level are disunited by time intervals Δt.

We can interpret this consequence in the other way. Suppose, we exercise an influence at the second level on a m-field twice in series (for example, we measure the coordinates of a quantum particle). The time interval Δt must pass after the first influence, then the second influence can be exerted. Otherwise, it needs a m-field which would infringe the third postulate. That is, two successive influences on the manifestations of a m-field at the second level can not be exercised during a time interval less than Δt.

Consider the question why fields are chosen as carriers of four fundamental forces but not particles. According to consequence number 6 external fundamental fields exert influence only on a wave function of a m-field. As it follows from the Schrödinger equation such influence has a nonlocal nature. That is, an external field interacts with a wave function at a multitude of points in space at one and the same time instant. If the carriers of fundamental forces are particles, then with what do they interact at points of multitude in space at one and the same time instant? If it is the particle on which they exert interaction in this case this particle must present at every point of space from this multitude simultaneously. But this is nonsense. If we suppose that particles are carriers of fundamental forces interact with a wave function at every point of space then by what does it differ from the field conception? That is using particles as carriers of fundamental forces, we obtain the field conception but more difficult and contradictory in this model. Adding to the above, if we suppose that the carriers of fundamental interactions are particles then they also must comply with lows of this model. But this leads to more difficult picture of fundamental interactions.

It is worth to note that we have got a deep connection between the statement about existence of a wave function as an element of reality and the question about what are the carriers of fundamental interactions.

Consequence 8. It follows from consequence number 3 and the fourth postulate that the picture of the fundamental fields of a quantum particle becomes more complex in comparison with the conception of classical physics due to the absence of a trajectory of a particle. Suppose, the manifestation of a m-field as a quantum particle occurs at a point A at a time instant t_0. In accordance with consequence number 3 the particle exists at the point A during the time interval

Δt. Then, the signal of fundamental fields corresponding to this particle springs from the point A with velocity of light in vacuum. Geometrically, the signal is a sphere with the center at the point A, with the width $c\Delta t$, and its radius increases with time $R = c(t - t_0) + R_0$, $(t > t_0)$. Where R_0 is the radius of the particle (look consequence number 1). Further, the next manifestation of the m-field occurs at a point B at a time instant $t_0 + \Delta t$. Then the new signal of the fundamental fields of this particle springs from the point B, etc.

Hence the fundamental fields of a quantum object consist of superpositions of signals, the above-described, springing at different time instants from different points. Thereby, we have come to a quantization of fundamental fields and a signal is a quantum of fundamental fields.

Consequence 9. As we can see from consequence number 8 a superposition of electromagnetic field signals of a single charged quantum particle has a different from classical theory of electromagnetic field conception geometry. For example, electric field lines can interrupt at borders of signals. Thus, Maxwell's equations not always fully applicable to electromagnetic signals of a single charged quantum particle. Except special cases, a superposition of electromagnetic signals of a single charged quantum particle turns to a classic picture of electromagnetic field by averaging at time and by passing to macroscopic scale.

Consequence 10. Let us consider the case of the elastic collision of two free quantum particles if there is no an interaction between them by means of fundamental fields or this interaction can be neglected. Make a hypothetical assumption that the coordinates, momenta and energies of these two particles are known at a time instant t_0, for some time before their collision. As it was shown in consequence number 4, a quantum particle does not have a trajectory. That is why we can not calculate definitely the relative position of these two particles at the moment of their collision. Consequently, we can not calculate definitely the momenta and energies of the particles after the collision, using the conservation laws.

This consequence can be formulated in the other way - when the given particle collides with another one, under the above described circumstances, we can not predict a certain correction which is caused by an influence on the first particle. This consequence is the fundamental limit to measurement accuracy in quantum mechanics.

Consequence 11. In accordance with the second postulate a m-field manifests itself as the quantum object in a definite state, this means that a momentum of the quantum object has one of eigenvalues of momentum operator. Then we can supplement the example of changing of spatial position by the quantum particle, considered in consequence number 3. At the points of the manifestations of the m-field A, B, C, ... the quantum object has definite, in general case different values of momentum, these momentum values are allowed by the wave function of this m-field. Hence if this quantum object collides with another at one of these points (interaction at the second level, see consequence number 6) exactly the manifested value of momentum in that manifestation of the m-field will be the parameter of interaction in this collision by consequence number 1 and consequence number 2.

As it follows from consequence number 3 momentum as the dynamic characteristic of classical mechanics can not be applied to the process of changing of spatial position by a quantum object.

It is worth to add that Heisenberg's uncertainty principle [3] takes the following meaning in this model. A quantum particle has a certain momentum and coordinates at the same time. But due to the existence of fundamental limits to measurement at the quantum level these two values can be gauged simultaneously only with limited accuracy. The mechanism of one of these fundamental limits is described in consequence number 10.

Consequence 12. Up to this point we keep that a m-field manifests itself as a single quantum object. The second postulate states that a manifestation of a m-field is subject to the wave function of this m-field. Thus, the system of quantum objects which is described by one wave function corresponds to one m-field. In this case the m-field manifests itself as several quantum objects.

Experimental test of Bell's theorem [4, 5, 6, 7] confirm the existence of entangled states if we estimate them in bounds of this model. It must be added that while developing of this model experiments for testing of Bell's theorem were significantly improved [8, 9, 10, 11] and finally the last loophole for hidden variables was eliminated [12, 13]. Thereby the existence of entangled states is considered experimentally proven in meaning as quantum mechanics interprets them. Consequently, a working model of a quantum object has to describe entangled states. This model of a quantum object does not have limits to a manifestation of a m-field consists of some quantum objects, being in an entangled state.

It follows from the second postulate that a manifestation of a m-field is subject to the laws of quantum mechanics. Then a m-field has to be subject to the superposition principle. The conception of a m-field has no limits to it. For example, suppose we have an atom in an excited state. Its wave function is a superposition of two states. The first one is the atom in the excited state. The second one is the atom in the ground state and an emitted photon by this atom. Thus, each manifestation of the m-field can occur in some of these two states. Note that the manifestation of the m-field in the second state consists of two quantum objects, being in an entangled state.

Consequence 13. As it was shown in consequence number 4 a quantum particle does not have a trajectory. Thus, identical particles are indistinguishable in this model.

Consequence 14. The collapse of a wave function is not described by the Schrödinger equation, hence the collapse does not occur when m-fields interact at the first level. In accordance with consequence number 6 m-fields interact at two levels. Consequently, this process occurs when m-fields interact at the second level.

It is worth to stress that a row of processes in a macroscopic object leads particles the object consists of to interaction at the second level. As a consequence we have permanent collapses of quantum states which the parts of the macroscopic object acquire.

It means that a process of direct measurement on a m-field leads to a collapse of its wave function or a collapse of a state which appears due to interaction of this m-field and a detector.

A mechanism of wave function collapse is in need of research, it is discussed below.

Now when the model of quantum object is built partly for the non-relativistic case let's apply it to a row of experiments, reflecting quantum effects. This model has to describe the processes, taking place in these experiments, to satisfy the claims of the working model of a quantum object.

Schrödinger's cat paradox

Let us take as example Schrödinger's cat paradox [14]. So we have a tiny bit of radioactive substance and the Geiger counter detects its decays.

Consider a single atom of radioactive substance. Quantum mechanics says that a wave function of an atom of radioactive substance is in a superposition of two states: the first state is the non-decayed atom, the second state is the decayed atom (an alpha-particle and the decayed atom). As it was shown in consequence number 12 a m-field, corresponding to this atom, manifests itself as the first state of the atom or the second one. A manifestation of the m-field in the first state means that the Geiger counter does not detect the alpha-particle. If the m-field manifests itself as the second state then the manifestation of the m-field as the alpha-particle happens inside the gas chamber of the Geiger counter. Any interaction between the alpha-particle and a manifestation of some m-field, corresponding to gas in the chamber, at the second level leads to the collapse of the wave function of the atom, accordingly consequence number 14.

Thus, the state of superposition will not be transmitted from the atom to the Geiger counter. The Geiger counter always will be in a definite state. Hence the cat has nothing to worry about.

Two-slit electron interference experiment

Let us consider the two-slit interference experiment with a single electron [15, 16]. Let the wave function of the electron pass through the slits. According to quantum mechanics the wave function of the electron divides into two parts, every of them passes through its own slit (and part of the wave function reflects from a screen with two slits). In accordance with the second postulate the manifestation of a m-field as the electron occurs in one of two slits. It follows from the third postulate the following manifestation as the electron occurs again in one of these slits in the time interval Δt etc. It is going to happen while the wave function is passing through the slits. After that the two parts of the wave function continue to spread in space behind the first screen with two slits, they interfere with each other. The manifestations of the m-field occur between the first screen and the second one. When the wave function reaches the second detecting screen and the m-field manifests as the electron on that screen the electron interacts with a detector, locating there. The manifestations of m-fields, corresponding to the quantum objects the detector consist of, interact with the electron. Consequence number 14 states that this interaction leads to the wave function of the electron collapses or the condition of the electron and the detector interaction collapses. The detector registers the electron at the zone of the manifestation. Hereby, the electron will be detected at the concrete point on the second screen.

The probability of a manifestation of the m-field as the electron on the detecting screen is subject to the laws of quantum mechanics. Therefore, making this experiment a sufficient number of times, we obtain an interference pattern, which quantum mechanics predicts.

Quantum tunneling

Finally we consider a tunneling of a particle through a potential barrier whose height is finite [17]. An incident wave function of the particle divides into two parts after an interaction with the potential barrier. The first part is a reflected part from the barrier and the second part is a passed part through the barrier. Thus, there are two regions of space where a probability to find the particle is non-zero. As pointed out in the first postulate this particle and its wave function are parts of a m-field. It follows from the second postulate and consequence number 12 that manifestations of the m-field as the quantum particle occur at the both regions of space. The probabilities of manifestations of the m-field as the particle are subject to a prediction of quantum mechanics. These manifestations are separated by time intervals Δt in accordance with the third postulate.

According to quantum mechanics, the wave function is non-zero inside the potential barrier in the course of their interaction. Hence, the m-field can manifest itself as the particle inside the barrier when the wave function interacts with the barrier.

Notice that it is enough the Schrödinger equation to describe a quantum tunneling process and there is no necessity to resort to the time-energy uncertainty relation to explain how a particle can pass through a potential barrier. The time-energy uncertainty relation will be discussed in consequence number 17.

Consequence 15. Let us consider the mechanism of collapse of wave function in detail by the example of a following thought experiment. A motion of a wave function of a particle is directed to a potential barrier, a barrier height exceeds an energy of the particle. Due to the tunneling effect the wave function of such particle divides into two parts $\Psi = \alpha\Psi_1 + \beta\Psi_2$, where $\alpha\Psi_1$ - the penetrated through the barrier part, and $\beta\Psi_2$ - the reflected from the barrier part. As in experiments we observe $|\Psi|^2$ mediately, but not Ψ, it is correct to talk about a collapse of $|\Psi|^2$, but not about a collapse of Ψ. We have $|\Psi|^2 = |\alpha|^2|\Psi_1|^2 + |\beta|^2|\Psi_2|^2$. Let $|\Psi_1|^2$ moves to the first detector of particles and $|\Psi_2|^2$ moves to the second one. In addition the detectors are located the way so $|\Psi_1|^2$ reaches the first one far earlier than $|\Psi_2|^2$ reaches the second one. A m-field of our particle manifest itself as the particle in states $|\Psi_1|^2$ and $|\Psi_2|^2$. As a detector is a macroscopic object so the time of interaction of $|\Psi_1|^2$ with the first detector - T_{int} exceeds Δt considerably. Therefore the probability that the m-field manifests itself as the particle in state $|\Psi_1|^2$ during T_{int} goes to unity. But such events will lead to an interaction at the second level of our m-field with a m-field of one of particles the first detector consist of. Denote this particle of the first detector D_1. In accordance with consequence number 14 it will lead to the collapse of the state $|\Psi|^2 = |\alpha|^2|\Psi_1|^2 + |\beta|^2|\Psi_2|^2$. In this case if $|\Psi|^2$ always collapses to $|\Psi_1|^2$ and we carry out such experiment any number of times all particles would be detected only by the first detector. But it contradicts quantum mechanics. Hence, $|\Psi|^2$ collapses to $|\Psi_1|^2$ or to $|\Psi_2|^2$ with corresponding probabilities. But what happens with the condition of the particle D_1 in this case? The collapse of $|\Psi|^2$ to $|\Psi_2|^2$ can not lead to a changing of a state of D_1 in spite of the interaction at the second level. In other case the both detectors would detect our particle. The mechanism of wave function collapse must resolve this dilemma. There are two the most likely variants of the mechanism of collapse for the superposition state of $|\Psi|^2$. The first one - $|\Psi|^2$ collapses, but the interaction at the second level do not lead to the changing of the state of particle D_1. If $|\Psi|^2$ collapses to $|\Psi_1|^2$ then subsequent manifestations of the m-field as the particle in the state $|\Psi_1|^2$ lead to a detection of our particle by the first detector. If $|\Psi|^2$ collapses to $|\Psi_2|^2$ then the second detector detects our particle. The second variant of the mechanism of collapse of $|\Psi|^2$ - if $|\Psi|^2$ collapses to $|\Psi_1|^2$ then it leads to the changing of the state of particle D_1 and to a corresponding changing of $|\Psi_1|^2$ in accordance with the interaction of m-fields of our particle and D_1 at the second level. As a result the first detector detects our particle. If $|\Psi|^2$ collapse to $|\Psi_2|^2$ then the state of the particle D_1 does not change and the second detector detects our particle.

To find out which of these two mechanisms of collapse of wave function corresponds to the objective reality is possible only by an experimental way. We describe an experiment which gives an answer this question below.

Consequence 16. In the third postulate there is an introduction of the tiny and fixed time interval Δt in which every manifestation of a m-field changes the previous one. Can Δt be an infinitesimal interval of time? We demonstrate that Δt must be exactly a finite interval of time. Let us consider the case of the elastic collision of two free quantum particles if there is no an interaction between them by means of fundamental fields or this interaction can be neglected.

According to this model of a quantum object we have two m-fields, each of them corresponds to one of our particles. Each m-field has a wave function in shape of a plane wave. Suppose that Δt is an infinitesimal time interval. In this case in accordance with the second and third postulates a m-field will manifest as a quantum object infinite number of times during any finite time interval. Hence, the number of interactions of manifestations of one m-field with manifestations of another m-field at the second level will be infinite during the time while two wave functions overlap each other in space. That is, our particles will undergo infinite number of collisions. In accordance with consequence number 11 and consequence number 14 every such collision leads to a redistribution of momenta of particles corresponding to the law of conservation of momentum, collapses of wave functions and productions of new ones in shape of plane waves with new momenta and energies. Hence, momenta of our particles change infinite number of times in a random way. It means that the average momentum of each from two particles will be equal zero. That is, our two particles will "hold" each other infinitely and never fly away in different directions from one area of space. Hence, time interval Δt can be only finite.

Consequence 17. As the third postulate states two manifestations of a m-field are disunited by the time interval Δt, in accordance with consequence number 16 Δt is a finite interval of time. Then we can introduce a time operator in quantum mechanics. Consider a m-field of a particle with a wave function $\Psi(\vec{r}, t)$. Let the m-field manifest itself as the quantum particle in the moment of time t_0, $t_1 = t_0 + \Delta t$ and $t' \in [\, t_0\,, t_1)$. Then the action of the time operator $\hat{t}$ on $\Psi(\vec{r}, t)$ in the moment of time t' can be described a following way according to consequence number 5. Before the moment of time t_1 the wave function $\Psi(\vec{r}, t)$ evolves by the Schrödinger equation, in the moment of time t_1 a manifestation of the m-field as the particle happens.

$$\hat{t}\,\Psi(\vec{r}, t') = \mathrm{M}_{\mathrm{II}}(t_1)\Psi(\vec{r}, t_1),$$

where $\mathrm{M}_{\mathrm{II}}(t_1)$ is the manifestation of the m-field at the second level as the particle in the moment of time t_1 and $\Psi(\vec{r}, t_1)$ is the evolved by the Schrödinger equation $\Psi(\vec{r}, t')$ over the time from t' to t_1.

Calculate the commutator of the time operator and the Hamiltonian

$$[\hat{H}, \hat{t}\,]\,\Psi(\vec{r}, t') = \hat{H}\,\mathrm{M}_{\mathrm{II}}(t_1)\Psi(\vec{r}, t_1) - \hat{t}\,i\hbar\,\frac{\partial\Psi(\vec{r}, t')}{\partial t} =$$

where the Hamiltonian $\hat{H} \overset{\mathrm{def}}{=} \hat{H}(\vec{r}, t)$ depends on time. From consequence number 6 it follows that the operator $\hat{H}$ does not act on a manifestation of a m-field as a particle, hereby $\hat{H}\,\mathrm{M}_{\mathrm{II}}(t_1) = \mathrm{M}_{\mathrm{II}}(t_1)\,\hat{H}$. The operator $\hat{t}$ commutates with a partial derivative with respect to t.

$$= \mathrm{M}_{\mathrm{II}}(t_1)\,\hat{H}\,\Psi(\vec{r}, t_1) - \mathrm{M}_{\mathrm{II}}(t_1)\,i\hbar\,\frac{\partial\Psi(\vec{r}, t_1)}{\partial t} = 0.$$

This result shows that there is not any reason to interpret a time-energy uncertainty relation as a possibility for a particle to acquire additional energy

ΔE for a time interval Δt (that is, a violation of the law of conservation of energy in small time scale) in this model. Also such interpretation directly contradicts to the second postulate, according to which a energy of a manifestation of a m-field is strictly defined by its wave function.

Consequence 18. The second postulate points out that a wave function gives the set of definite states a m-field can manifest itself. But the wave function does not limit the dimension and form of a manifestation of a m-field. Therefore, this model does not forbid states in which a quantum object occupies more place in space than its wave function. And vice versa the dimension and form of a quantum object do not restrict the wave function of this quantum object including its spatial configuration.

Experiments with the observation of interferences of large molecules [18, 19] confirm that the large molecules of different forms have wave nature however their wave functions have spatial configurations, changing considerably at distances much less than the dimensions of these molecules.

Why is an object m-field introduced in this model? Why would not we just entrust the role of the m-field plays to a wave function of a particle? It follows from the first and third postulates that manifestations as a quantum object in different points of space must obey the system. For this reason an object which is responsible for manifestations must unite all possible points of space where the probability of a manifestation differs from zero. If this object is disunited in space to parts then there is a necessity of some signals between these parts for a concord of manifestations as a quantum object between each other. In a raw of cases a wave function has nodal surfaces, in which its value equals zero. For example a wave function of an electron in an atom of hydrogen has such nodal surfaces in the shape of spheres [20]. Strictly speaking, a wave function of an electron absents at points of such sphere and this sphere disunites a wave function to two parts. It means that some concord signals are needful between these parts of a wave function. These signals must move through the sphere. But a wave function does not have such signals and an introduction of them into the model is not reasonable. In its turn, an object m-field exists at every point of space-time continuum, hence, it satisfies the above-described requirement.

On the other hand, the fourth postulate entrusts the function of transmission of fundamental interactions to the object m-field. To entrust the function of transmission of fundamental interactions to some object this object must satisfy at least one of two requirements:

1. An object must exist at every point of space-time continuum.
2. An object must move with velocity of light.

As a wave function does not satisfy no one of these requirements we can not entrust the function of transmission of fundamental interactions to it. That is the elimination of a m-field from the model demands a corresponding substitution for fundamental interactions. In sum, on the one hand, we have the intrusion of some concord signals in the model and intrusion some alternative for four fundamental interactions, but on the other hand, we have an object m-field. In accordance with Occam's razor principal the second variant is preferable.

3 The relativistic case

Let us discuss this model in the bounds of special theory of relativity (STR).

Consequence 19. It is important to stress that STR operates with a classical concept of material object motion. But the concept of "classical motion" is not applicable to quantum objects in this model (see consequence number 4). In this model a spacetime interval between two manifestations of a m-field as a particle cab be anyone. That is if we refer to the example, described in consequence number 3, a spacetime interval between the point A in the instant t and the point B in the instant $t + \Delta t$ cab be as timelike and as spacelike.

The third postulate is based on a concept of time. In STR time flows with different speed in different inertial frames of reference. In our model this effect acts for the first level of m-fields because a wave function is a function of time. If this effect is applicable to the third postulate a picture of an interaction of quantum particles will become paradoxical. To synchronize an interaction between quantum objects if time flows differently for their wave functions introduce the fifth postulate.

Postulate 5. *The time interval between two manifestations of a m-field* Δt *does not depend on relativistic effects.*

It means that if we consider two m-fields the wave function of the first one rests with respect to our inertial frame of reference and the wave function of the second moves with any velocity with respect to our inertial frame of reference, manifestations of these m-fields occur simultaneously. In fact, we come to the conclusion that manifestations of all m-fields in the Universe occur simultaneously and in the same time intervals Δt.

Consequence 20. The both variants of the mechanisms of a collapse of a superposition state $|\Psi|^2 = |\alpha|^2|\Psi_1|^2 + |\beta|^2|\Psi_2|^2$, described in consequence number 15, allow experimentally to distinguish by a statistical method superposition states $|\Psi|^2$ from free states $|\Psi_1|^2$ and $|\Psi_2|^2$, which appear after collapses of states $|\Psi|^2$. Hence, making collapses of states $|\Psi|^2$ or not making them, we can transmit signals at a speed more than the speed of light. Below in section number 5 “Experimental verification of the given quantum object model” a principal of such transmission of signals is described.

4 Gravitation

Let us consider the gravitational field of a quantum particle of finite mass. Let a wave function of the particle rests with respect to our inertial frame of reference. In accordance with general theory of relativity (GTR) gravitation is a curvature of space-time continuum. If we present gravitation as a curvature of space-time continuum in this model, that brings us to the following deductions:

1. Consequence number 8 says that gravitation of a quantum particle is a superposition of signals, springing at different time instances from different points. Exactly these signals curve space-time continuum. In this case if we describe a curvature of space-time continuum by a function then such function will have discontinuities on edges of spreading signals.
2. Space-time continuum is an outer object relative to a m-field. Hence the wave function of a m-field undergoes the influence of gravity signals, generated by manifestations of this m-field. As a result, we face inevitably an influence of a quantum particle on itself for gravity.

5 Experimental verification of the given model of a quantum object

To verify this model experimentally it is necessary to suggest and carry out an experiment where predictions of this model would differ from predictions of quantum mechanics. For this goal it is convenient to use the mechanism of collapse of wave function in state of superposition, described in consequence number 15. For simplicity of reflections let in $|\Psi|^2 = |\alpha|^2|\Psi_1|^2 + |\beta|^2|\Psi_2|^2$, $|\alpha|^2 = |\beta|^2 = 1/2$, that is, the reflected from the barrier part of the wave function $\Psi = \alpha\Psi_1 + \beta\Psi_2$ equals the penetrated through the barrier part. Let N particles impinge on the barrier every time unit and their wave functions pass into superposition states Ψ. That is, we have the flow of particles, for example electrons, in the states $|\Psi|^2$. Let Ψ_1 - the penetrated through the barrier part of the wave function of a particle moves to Alice and Ψ_2 - the reflected from the barrier part of the wave function moves to Bob. In addition parts $|\Psi_2|^2$ reach Bob's experimental setup earlier than parts $|\Psi_1|^2$ reach Alice's experimental setup. Bob's experimental setup is made the way it can make collapse of the state $|\Psi|^2$. For example, Bob can put a detector on the way of particles in the flow or take it away. Alice irradiates coming to her particles by photons at her setup. Let a concentration of photons at Alice's setup is adjusted the way that only a part of particles in the flow collide with photons. Let P be a probability of a collision of a photon and a particle in the state $|\Psi_1|^2$ (that is, P is the probability of a collision of a photon and a particle, when the state $|\Psi|^2$ of this particle has collapsed to $|\Psi_1|^2$ because of Bob's action) and Alice counts scattered by particles photons using special meant for it detectors.

The first case, Bob induces collapses of states $|\Psi|^2$. Then statistically $N/2$ particles reach Alice's setup in the state $|\Psi_1|^2$ for time unit. Hence, a quantity of scattered photons for time unit equals $N(P+P^2)/2$. The term P^2 corresponds to a probability of a collision of a particle with the second photon, after the first collision.

The second case, Bob does not induce collapses of states $|\Psi|^2$, the first variant of mechanism of collapse of superposition state. Then in accordance with consequence number 12, a m-field, corresponding to a wave function Ψ, manifests itself as a particle in one of two states $|\Psi_1|^2$ or $|\Psi_2|^2$ in time intervals Δt. Since $|\alpha|^2 = |\beta|^2 = 1/2$, so a m-field manifests itself as a particle in Alice's setup statistically two times rarer than in the first case. Hence, the probability of collision of a particle with a photon two times less than in the first case. Then $NP/2$ particles collide with photons in Alice's setup for time unit. According to consequence number 14 it will lead to a collapse of the state $|\Psi|^2$ of such particles. A half of these $NP/2$ particles pass into the state $|\Psi_1|^2$ and the second half pass into the state $|\Psi_2|^2$. But a state of a photon does not change after a collision with a particle. A photon will not be scattered by a collision with a particle accordantly to the first variant of mechanism of collapse. After the first collision with a photon, a particle, the wave function of which has collapsed to $|\Psi_1|^2$, continues its motion in Alice's setup. With the probability P^2 it can collide with one more photon. In accordance with the first variant of mechanism of collapse this (the second) photon will be scattered by a particle and photon detectors catch this scattered photon. Hence, the quantity of scattered photons will equal $NP^2/4$ for time unit.

The third case, Bob does not induce collapses of states $|\Psi|^2$, the second variant of mechanism of collapse of superposition state. Then in accordance with consequence number 12, a m-field, corresponding to a wave function Ψ, manifests itself as a particle in one of two states $|\Psi_1|^2$ or $|\Psi_2|^2$ in time intervals Δt. Since $|\alpha|^2 = |\beta|^2 = 1/2$, so a m-field manifests itself as a particle in Alice's setup statistically two times rarer than in the first case. Hence, the probability of collision of a particle with a photon two times less than in the first case. Then $NP/2$ particles collide with photons in Alice's setup for time unit. According to consequence number 14 it will lead to a collapse of the state $|\Psi|^2$ of such particles. A half of these $NP/2$ particles pass into the state $|\Psi_1|^2$ and the second half pass into the state $|\Psi_2|^2$. According to the second variant of mechanism of collapse if $|\Psi|^2$ collapses to $|\Psi_1|^2$, then a photon will be scattered after a collision with a particle, if $|\Psi|^2$ collapses to $|\Psi_2|^2$, then a photon will not be scattered. That is, $NP/4$ particles turn out in the state $|\Psi_1|^2$ in Alice's setup and the same quantity of photons will be scattered. After the first collision with a photon, a particle, the wave function of which has collapsed to $|\Psi_1|^2$, continues its motion in Alice's setup. With the probability P^2 it can collide with one more photon, which will be scattered. Hence, the quantity of scattered photons will equal $N(P+P^2)/4$ for time unit.

That is, Alice can distinguish experimentally superposition states of particles from free states of particles. If Bob induces collapses of states $|\Psi|^2$ (the first case), then Alice receives a signal "0", if Bob does not induce collapses of states $|\Psi|^2$ (the second case or the third case) then Alice receives a signal "1". Thus we can transmit signals at a speed higher than the speed of light.

Predictions of quantum mechanics for all three cases equal the result for the first case, that is, the quantity of scattered photons will be equal $N(P+P^2)/2$ for time unit.

The quantity of particles N has to be adjusted the way the interaction between particles in a flow does not lead to collapses of their wave functions Ψ. To make a technical realization of the experiment easier photons can be used on the role of particles in a flow. In this case, for example electrons can be used instead of photons in Alice's setup.

As we can see this experiment allows us not only to verify the suggested model of quantum object experimentally, but to find out which of mechanism of collapse of wave function exactly realizes physically.

Conclusion

It is important to note that the concept of a m-field is an object which owns the properties of a wave and of a particle simultaneously. It gives us a completely new way of looking at the wave-particle duality problem. The wave-particle duality is not an unthinkable notion any more.

The predictions of the given model differ from the predictions of quantum mechanics in separate cases. It gives us a possibility to verify this model experimentally. This allows to shift a question about the validity of this model from the subject of philosophy to the subject of physics.

This model contains the new information about micro-world, which can potentially help to solve the row of the problems QFT faces.

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