QUANTUM ENTANGLEMENT, ITS NATURE AND MANIFESTATIONS

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ABSTRACT

Quantum informatics is now one of the most progressive branches of theoretical physics combining quantum mechanics with informatics. Quantum informatics concentrates its attention to the three directions: development of quantum computer, quantum cryptography and quantum teleportation. The development of these spheres needs deeper penetration into quantization of matter. Although the apparatus of quantum physics is carefully formulated and precisely verified by experiment, the great problems are with interpretation of quantum phenomena. My aim is to explain the nature of quantum reality in order to remove the interpretational problems of quantum theory and open new horizons for its future development.

THE NATURE OF QUANTUM PHENOMENA

In my previous articles I have deduced, by using a dialectic logic, that the Universe consists of elementary bipolar connections of opposite poles "+" and "-" which are named quantum dipoles, where every "+" is connected with all "-" poles of the Universe and reciprocally. Everything is connected with everything at the quantum level. So the Universe as a whole represents a dynamic and increasing network of elementary bipolar relations.

Quantum mechanics describes the motion in the micro-world mainly by Schrodinger´s probabilistic wave function. Although mathematical formalism is clear, the nature of quantum phenomena has not been understood. The famous physicist of 20-th century – Richard Feynman even said, that nobody can understand quantum physics. The main interpretational problems occur mainly if we study the relations between the macro and micro worlds. Analogical is the situation with understanding the reason for an existence of the so-called uncertainty principle and probabilistic character of quantum phenomena.

The behaviour of the quantum system can be described by the wave function. But as soon as we measure one of quantum characteristic, e.g. spin of particle, the wave function collapses and the measured characteristic obtains one concrete value. The measurement causes the considerable intervention into the quantum world and changes its behaviour. It is impossible to obtain the information about the micro-world without measurement, which nevertheless changes its state. This fact and the problem with determination of the border line between the macro and micro world sometimes causes extreme subjective interpretations, according to which reality is a product of our consciousness. The observer plays the main role by experiments, as he directly influences the quantum phenomena by his decisions about what to observe and how to measure. Some physicists suppose the absence of objective reality, the others argue that there is a limit to our ability to know the essence of quantum phenomena and so they become sceptics and agnostics.

The measurement of the observed system is obviously performed by sending a photon, which, after interaction, carries the information in the form of its own changed state (amount of energy, polarisation, e.g.). The interaction of the photon with the observed quantum system causes the collapse of the quantum function, which obtains one of the possible states having certain probability amplitudes before measuring. The Copenhagen interpretation includes the quantum objects and classical measuring apparatus in an inseparable system and the collapse of the wave function is considered a necessary result of the mutual connections between the micro and macro world.

Now, knowing the mutual interconnection of everything with everything, it is no problem to interpret the interactions between the measuring and quantum systems as any other interactions between two or more systems consisting of elementary quantum dipoles. So, all relations between the measuring apparatus and measured quantum objects are only parts of the universal cosmic network of elementary quantum interactions creating the objective physical reality, independent of a human consciousness. But the observer, as a conscious subject, plays an active and creative role in his communication with the micro-world.

The polemics is also about Heisenberg´s uncertainty principle, according to which the simultaneous precise spatial position and velocity (or momentum) of the particle cannot be defined. The question is: Is this the basic principle of the micro-world or only a consequence of measuring limitations? The classical physicists suppose that the particles dispose of these properties, only we cannot measure them simultaneously. The quantum physicists consider the uncertainty principle to be the fundamental property of the micro-world, but they do not know its reason. The answer is not difficult at all. Every bipolar quantum connection (dipole) is a holder of an elementary quantum of space. So the particle has no precise position in space, as it contains (holds, carries) the certain quanta of space and all its external quantum connections, coming from it, are also the spatial holders. Its position can be expressed only in relation to the other spatial quanta. So the question about determination the precise spatial coordinates of a particle is not correct at the quantum level.

The motion of the particle is represented by the motions of its internal quantum dipoles (**internal motion of particle**) as well as by the motion of its outgoing external quantum dipoles manifested by their shortening or elongating (**external relative motion of particle**). These are not the motions in space, but the motions of some spaces towards others. It is remarkable that Einstein connected matter and space together at the macro level in his theory of gravity, but at the same time, he differed them at the quantum level, and the motion of the particle was represented as the motion of a mass point (internally homogenous corpuscle) in space without understanding that space created by the particle (short internal quantum dipoles) is, on principle, the same as space created by the vacuum (long external quantum dipoles between objects). The material bodies (particles) and vacuum differ only by the length and energy of their quantum connections (dipoles). It is necessary again and again to emphasize, that the presentation of the particle as a mass point or corpuscle without any internal structure and space, is an idealisation unacceptable in the quantum world. So the question about the determination of the precise spatial particle position is incorrect. Quantum physics has not understood that elementary particles hold a certain quanta of space. Instead of studying their spatial manifestations and relations to the other spatial quanta, it accepts their strange behaviour to be in various spatial places at the same time. But this is only a consequence of the fact, that the particle can manifest itself outwards through its various external connections at the same time, what evokes an illusion that the particle is simultaneously in different places.

Heisenberg´s uncertainty principle is a result of trying to apply the procedure of classical physics to define the spatial position and velocity (momentum) of a particle. But in reality, in any moment, all relations (elementary quantum connections) are exactly determined, real and objective in the quantum world. Quantum physics does not investigate the real nature of the quantum world, but only its relations and manifestations towards introduced coordinate systems or measuring apparatus. Of course, according to these manifestations, we can only deduce that the uncertainty dominates in the quantum world.

The probabilistic character of quantum phenomena becomes clear, if we accept the connections of everything with everything and the consequent impossibility to select an isolated quantum system. Every selected system is totally connected with the whole Universe, influences it and is influenced by it. These universal connections cause individual quantum phenomena as seeming to be probabilistic and unpredictable. It is impossible to include the global cosmic activity into a separate mathematical model. If we want to study the certain system, we must select it from the totality. If we study the relations, states and processes of the selected quantum system, we are not able to take into account all external influences, so we consider them as accidental and the behaviour of quantum system as probabilistic. Now we can clearly see why the decoherence phenomenon is so important and limiting in quantum physics and why it causes the decay of selected quantum systems. It is impossible to isolate the quantum system from the direct actions of its surroundings. The quantum states, like spin or polarisation, of the selected quantum system (e.g. particle) are manifested only in relation to the other systems (bases), for example, a coordinate system or magnetic apparatus with its magnetic field. So we study the basic states of the quantum system in a chosen representation (in relation to the chosen basic system). The ability of the quantum object to manifest outwards in various forms is interpreted as its possibility to exist in superposition of various quantum states at the same time. Quantum physic examines carefully the transitions between the representations, towards which the quantum states are defined. As the selected quantum object has different manifestations towards different bases, their mutual relations are searched in the form of transformational matrixes transferring the basic quantum states in one representation to the other.

The motions of internal quantum dipoles of two observed particles are coordinated by their external mutual connections. This mutual coordination is interpreted as interference or correlation of their quantum states expressed by the interference of probability amplitudes. If we investigate two particles separately, the sum of probability amplitudes of their quantum states does not correspond to the probability amplitudes of quantum states of both particles, if we investigate them as one quantum system. It means that two particles are mutually interconnected and their internal motions, manifested outwards by their spins, are mutually coordinated. The entanglement of quantum states of both particles, creating one quantum system, is a consequence of their direct mutual connections. Two identical particles can interfere by two different ways. If their probability amplitudes are summed with a positive sign, they represent Bose´s particles (bosons): photon, inter-medial bosons. If the sign is negative, they are Fermi´s particles (fermions): electron, neutrino, nucleons, baryons. Bosons are particles with the integral spin, mainly j=1, fermions with half-integral spin, mainly j=1/2. The spin j=1/2 means, that the particle can deflect into the one of two possible directions in a magnetic field. The spin j=1 means, that it can choose one of three possible directions (one without deflection). The particles with the spin j=0 do not deflect in a magnetic field.

QUANTUM COMPUTERS

The differentiation of quantum states is the basic condition for the creation of quantum information systems with the elementary units known as qubits – two-state quantum elements. Two different states of the quantum element are expressed by two signs 0 and 1, which represent one bit of information. The elementary particles, which can exist as minimum in two different quantum states, are the appropriate candidates for the qubits, e.g., photons with different states of polarisation or leptons with two different spin states.

The creation of the quantum computer supposes the formation of multi-bit memory registers consisted of the system of qubits, through which the logical and calculating quantum operations are performed. The effect of quantum computers lies not only in a remarkable miniaturisation and acceleration of calculating operations, but mainly, in a specific property of quantum systems known as quantum parallelism, thanks to which the qubit creates a superposition of its quantum states 0 and 1. Such a memory register is capable of holding $\mathbf{2^n}$ values simultaneously (**n** – the number of qubits in one register), while the classical register - only one value (number). The quantum register enables to manipulate with $\mathbf{2^n}$ amplitudes simultaneously, causing an enormous increase in efficiency of such computers, thanks to the exponential acceleration of some algorithms. The great success on the way to the practical application of the quantum computers was achieved by the creation of the quantum Turing machine and the development of quantum computing algorithms. But the greatest barrier, radically limiting the lifetime and practical applications of quantum computers, represents the phenomenon known as decoherence of quantum systems.

As everything is connected with everything else, it is impossible to isolate the quantum computer form its environment, so it is necessary to find the mechanism, correcting the influence of surroundings in order to prevent the selected quantum system, e.g. quantum computer, from decay. This is a serious problem for quantum informatics and its effort of building a stable quantum computer.

TELEPORTATION

The other areas of quantum informatics, independent of the existence of quantum computers where the great experimental successes have been achieved, are in quantum cryptography (coding, transmission and decoding of secret information) and quantum teleportation.

Now we are going to deal, in more detail, with quantum teleportation based on the phenomenon known as entanglement. This phenomenon is the manifestation of universal connections of everything with everything, where every elementary quantum dipole is connected with all others. The quantum teleportation is based on the phenomenon resulting directly from quantum physics and known as the EPR non-locality, which was firstly detected by Einstein, Podolsky and Rosen. This phenomenon represents the basic principle of quantum mechanics, when two spatially separated subsystems of the observed system are mutually connected. So, if two particles create one entangled quantum system, knowing the spin of one particle we automatically know the spin of the other, independent of how distant they are. If we change the quantum state of one particle, the quantum state of the entangled particle is changed at the same time.

The direct immediate action at a distance was refused for a long time as it contradicted Einstein´s locality principle. But it was verified many times and the teleportation of quantum states has been performed.

The entanglement supposes the division (decay) of the quantum system into the mutually connected subsystems. Then a part of original internal connections of the quantum system transfers into the external mutual connections between two or more subsystems, through which the quantum states of quantum subsystems are coordinated.

The selected quantum systems and their mutual connections can be effectively studied and analysed by the matrix, where every window (cell) represents a separate quantum dipole, which characteristics, like energy and length, can be registered in it. If we observe the quantum system in relation to a certain base (representation), than we can register such characteristics like spin or polarisation. All quantum connections coming from a certain quantum dipole are situated in the corresponding row and column.

The evolution of quantum characteristics (states) of the observed quantum dipole is influenced by the evolution of all others. Let us imagine the mutual relations between three dipoles in the following matrixes:

Poles	-	-	.....	-	-
+					
+		(+,-)			
+				(+,-)	
+					
+					
+					(+,-)

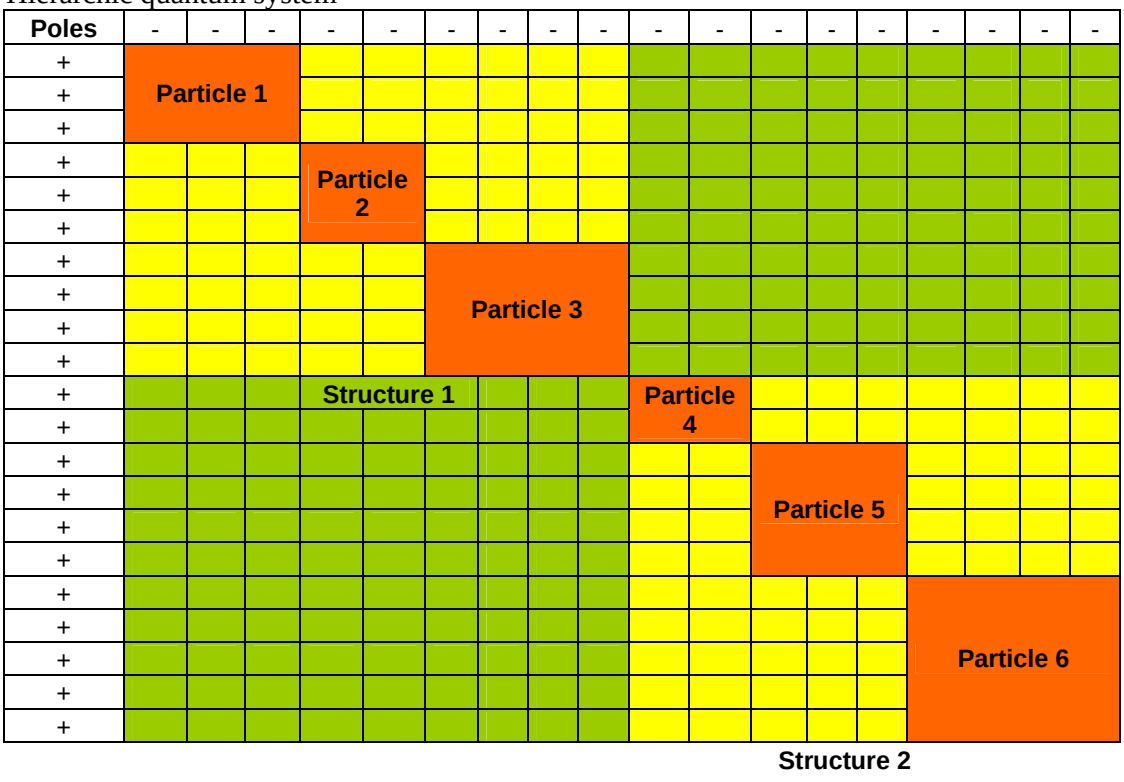
Poles	-	-	.....	-	-
+	(+,-)				
+		(+,-)			
			(+,-)		
+					
+					
+					
+					

The mutual connections between three selected quantum dipoles (dark green colour) are represented by the intersections of columns and rows (chartreuse). If the dipoles create a compact quantum system, it is better to get them together. Then the quantum system (e.g. elementary particle) is represented by the green square with nine elementary quantum connections (dipoles). If three selected dipoles oscillate, their mutual connections only

respond to these vibrating motions without their own oscillations. But the bipolar connections can exchange their roles. If the system (particle) consists of nine quantum dipoles, their mutual motions are rather complicated for their precise description. They create the cumulative internal motion of the particle - its vibrating mode. The elementary particle oscillates, pulsates and rotates as a result of internal motions of its dipoles. If we want to detect the quantum states of the particle, we can only observe its manifestated motions towards the other systems, for example, measurement apparatus. The motion in the micro-world, observed through the changes of quantum states, is always performed by quantum jumps, when the length and energy of quantum dipoles are changing. These characteristics are internal. The other characteristics, like spin, are relative as they occur in relation to the other systems. The quantum object is a classical cybernetic black box, whose internal structure is studied through its external manifestations. I am sure that the detection of the elementary quantum dipole as a building block of the Universe can give quantum physics the effective instrument for studying the micro-world. The main goal is to remove the interpretational problems of quantum physics.

Analogically, as we have described the relations between elementary quantum dipoles, we can imagine the mutual connections between more complicated quantum systems by the following matrix:

Hierarchic quantum system



The picture interprets the four-level quantum system consisting of two structures with their green mutual connections. The structures consist of red particles with yellow mutual quantum connections. All particles and their mutual connections are created by the elementary quantum dipoles.

If our quantum dipole is a part of the well defined structure, e.g. particle, its quantum characteristics are considerably influenced by the other quantum dipoles of this particle. Quantum states of the particle are the function of motions of its internal quantum dipoles as well as external quantum connections with surroundings. More particles can create a coupled quantum system, which cannot be isolated from the surroundings. It is impossible to observe the influence of all external connections. But if we want to struggle against the decoherence of quantum systems like the quantum computer, we need to eliminate the influence of external quantum connections in order to guarantee the dominance of its internal quantum dipoles. It supposes to build the external multilevel protecting and correcting system which is able to correct the influences of surroundings in such a way that the observed quantum system will behave as though independent of its surroundings.

The quantum teleportation is not the real teleportation of physical bodies as it does not represent the direct immediate transfer of a massive object from one place to the other. What is meant is its disappearance in one place and appearance in the other. The quantum teleportation is only a transfer of the quantum state from one part of the entangled quantum system to the other. The information about the measured quantum state of one part is transferred, by the classical information channel, to the other one, where the replica is created. So, the transferred quantum state is performed on different quantum dipoles than the original. This teleportation means the decomposition of the object in one place and composition of its copy in the other.

But real teleportation means the direct immediate transfer of a massive object from one place to another, thanks to the transfer of energy from some external quantum connections of the object to the others, as the energy and length of quantum connections (dipoles) are inversely proportional. If we want to teleport our massive object to the certain final place, we must radically shorten their mutual connections by transferring the energy to them from the rest external connections of the massive object. As these transferred energies are very low because of long vacuum quantum connections, it is necessary to find the way to transfer such low energies from the shorter external quantum connections of the object to the longer ones, in order to shorten them immediately and teleport the object to the final place.

If such energetic transfers are possible on principle, they could be performed by the special electromagnetic fields created around the teleported object. So the teleportation means of transport would be the machines creating the electromagnetic fields allowing the transfer of very low energies from one external quantum connections to the others. The existence of such transport machines would allow the people to travel through the whole Universe without any limits. The future will show whether this dream is pursuable. Now I have presented it only as a hypothesis.

The classical mechanical motion is caused by the action of forces between objects. The transfer of energy between quantum connections is performed step by step with what looks like continual spatial motion, although all motions are performed by quantum jumps as a consequence of quantum jumps of the Universe. If the mechanism for the transfer of higher quanta of energy from one long quantum connections to the others is discovered, the continual gradual motion changes into visible teleporting jumps.

When the elementary particles suddenly appear from the vacuum, it means that, thanks to the sudden energy supply, the considerable shortening of some quantum dipoles happens in the cosmic network of long quantum connections (vacuum) with the consequent immediate

creation of elementary particles. It is not the gradual but the immediate considerable shortening performed by the great quantum jumps. This fact promises that teleportation could become real in the future.

The direct action at a distance by the non-local quantum connections can be manifested by such phenomena like telepathy – the direct thought interconnection of persons, and psycho-kinesis – the direct action of thoughts to the material object and its motion.

The thoughts, created by the cooperation of the consciousness and brain, have a subtle energetic vibrating form and are connected with the whole Universe, what allows them not only to activate the biochemical and biophysical processes in the brain of its author, but, thanks to the long quantum connections, act directly to the thought sphere of the other person (telepathy). The consciousness, as a manifestation of the spirit activity, plays the main role by the creation of thoughts. The brain represents the instrument through which the consciousness forms the energetic form (structure and vibrating mode) of thoughts. In understanding the relation between the consciousness and brain two different approaches are possible. The materialistic position supposes that the consciousness is generated by the brain activity, so it has physical reason. Really, the biochemical and biophysical brain processes create the subtle dynamic energetic forms (structures) inside and around the brain, but they do not represent the whole consciousness, only its material manifestation. Is the consciousness only a function of the brain activity? In the idealistic understanding the consciousness has an immaterial character as a manifestation of spiritual activity. The brain is only the instrument for consciousness (spirit) which, during evolution, formed it from the simple to the most complicated form in order to manifest itself at the qualitative human level. By the cooperation between the consciousness and brain, subtle material vibrating structures of weak quantum connections are created. Thanks to the brain and nervous system, the consciousness can communicate with the outside world. The sense organs receive the external energetic vibrations, which the nervous system transfers in the form of electric impulses to the brain, creating such vibrating structures, which the consciousness can interpret as images, sounds, tastes, aromas, senses, etc. Contrarily, thoughts and stimuli, as a result of consciousness activity and its cooperation with the brain, are transformed to the required subtle vibrating structures activating the nervous system, which after transforming into electrical impulses, transfers them to the body organs, which react and perform the needed actions.

The way from the external impulses to the consciousness and from the internal stimuli of the consciousness to its bodily manifestations represents the relation between the subjective consciousness (spirit) and the objective external world.

The thoughts, imaginings and inspirations represent the highest spiritual level of consciousness. But they create the complicated energetic structures connected with the whole Universe by their external quantum dipoles. So, through thoughts and imaginings, it is possible to act directly at a distance and evoke phenomena like telepathy and psycho-kinesis.

Man is self-consciousness, and at the same time, the consciousness of his own world in himself. I cannot get outside my consciousness – my ego. My unconsciousness is only an aspect of my consciousness. All my existence (my world) is in my consciousness. The whole being of the Universe is contained in the universal self-consciousness of God. Matter as energy, space and time represents only an unconscious aspect of the universal consciousness.

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