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The Quantum Challenge from the viewpoint of Einstein's realism

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We studied the results of the experiments with the photons described in the book "The Quantum Challenge. Modern Research on the Foundations of Quantum Mechanics" by Greenstein and Zajonc and applied to them Einstein's point of view about the reality of the existing world and the necessity to find adequate notions to describe it.

We made a conclusion that the known statemets of physics can serve as these notions. Their joint application can be enough to explain a great amount of experiential data, that were non-explicable from the standpoint of orthodox interpretation of the quantum mechanics.

1. Introduction

In the work of George Greenstein and Arthur G. Zajonc "The Quantum Challenge. Modern Research on the Foundations of Quantum Mechanics" [1] after analyzing the results obtained in experiments with photons the following generalization was made:

«The experiment gives evidence that the particles cannot be viewed as separate objects even when they are located on a randomly big distance from each other. Even in this case the particles are sort of one object and we cannot attribute local, truly existing parameters to separate particles.

This object that does not have classic analogues can be in several places at once. Its parameters are related to the different parts of the system that can be on whatever big distance from each other and not have a real physical interaction. However, between these parts there is an instant correlation of measurement results. If we are ready to treat quantum mechanics seriously as a science that makes statements about real world then we must significantly change our perceptions about this world. We must admit that behind the world of objects that seem independent there is a kingdom of mixed states where the simple notions of causality and locality are not applicable anymore". (here and further the quotes are translated from Russian editions).

Albert Einstein who created the most perfect physical theories as of today, valued quantum mechanics and the perfection of its mathematical theory. However, he considered physical interpretation of its statements unsatisfactory, because it contradicted the foundation of his physical worldview that can be expressed by one short phrase – the world is real. In his article on interpretation of quantum mechanics foundations in 1953, he wrote:

"The only acceptable interpretation of Schrodinger's equation so far is the statistical interpretation given by Born. However, it does not describe the real state of a separate system but only allows making statistic expressions about ensembles of systems.

I believe it is essentially wrong to put these theoretical perceptions to the basis of physics because it is impossible to refuse the possibility to describe objectively a separate microsystem (or a "real state") without covering the physical image of the world "with a fog". At the very end, an idea that physics must aspire to describe a real state of a separate system seems unavoidable. The nature at large can be perceived only as a separate (existing on a single occasion) system and not as an "ensemble of systems". [2].

In this work we will try to show that the value of the mentioned above Einstein's program thesis does not decrease because of the phenomenon proved by many experiments and described by Greenstein and Zajonc, that is called "quantum nonlocality", and that the only clarification to be made here is the one of the notion of "separate microsystem".

What follows from the special relativity theory – the work of Einstein himself – the lifespan of the light beam (quant) in its own coordinates is always equal to zero, not depending on time and distance that it made in our coordinates. From here it immediately follows that the pair of photons, related ("entangled") at birth, must stay the same during all the time of their existence, because during the time equal to zero no physical event can happen, including also due to the violation of their entanglement [3]. Which gives us the reason to call "a separate microsystem" not every photon of this pair but the whole pair.

We believe that this approach allows to see from a new angle not only seemingly paradoxical results of Bell's inequality check but also other results of experiments with photons which seem today barely explicable and form a picture of "Quantum Challenge" described by Greenstein and Zajonc.

2. Dirac's quantum theory. Superposition principle

The creation of Dirac's quantum theory [4] begins with introduction of a new notion – the principle of superposition. Describing the experiments with photons polarizations Dirac considers it necessary to include the notion that he suggests to see as *"supplement to formulate rules that express the results of numerous experiments in a succinct format"*.

He describes it the following way: *"It is assumed that the photon polarized by angle to the optical axis, can be viewed as being in polarized condition partially to the parallel axis and partially – to the perpendicular axis.*

Further: *"Transmitting the photon through the tourmaline crystal, we observe it and establish if it is polarized in parallel or perpendicularly to the optic axis. Because of this observation, we transfer the photon fully either into the state of parallel polarization or the one of perpendicular polarization. It must make a sudden hop from the partial being in both of these states to being fully in any of these states"*.

But the approach based on derived from the special relativity theory conclusion about photon's own zero lifespan allows to describe this situation without state hops at the moment of measuring.

The photon does not remain in several possible states with sudden hop in any of them. It remains in one state, defined by the conditions on both ends of its path, as the interval of its own time between them is dt = 0. The photon kind of "glues" these two points of the space with each other (in their coordinates) simultaneously, so in the interval between the events in these points there cannot be any other physical events, including change of polarization, etc. In the experiment described by Dirac, the photon both flies out and is being registered by the detector at the same moment of its own time – the moment when the conditions for its absorption by one of the atoms of one or another detector are created. And precisely in the polarization that corresponds to this detector.

The same way we can describe the situation with the experiments on photons interference. In Dirac's description: *"Let the beam of light that goes through a certain interferometer split into two components that later interfere with each other. As in the previous paragraph, we can take a beam consisting from one photon and ask what will happen when it will go through the device"*.

"According to the description that we accepted in the case of polarization, we now, describing the photon's behavior, should believe that it will partially enter into each of two components, appeared after the beam has split. So we can say that the photon exists in the state of the forward motion that represents the superposition of the two states, corresponding to two components".

For the approach that we study, it is not important if the photon entered one component that the beam was split into or all of the components. It is important that it happened at the moment (of photon's individual time) when the conditions appeared for the connection of the radiation source with that atom of the detector that registered it as a result.

3. Dirac's moving mirror and informational interpretation of the experiments

Describing the experiment with the interferometer, Dirac, reasoning from the principle of superposition standpoint, asking the question about photon's energy: *"Let us see what is going to happen if we define the energy of one of the components. The result of this definition can be either the whole photon or nothing"*.

"We can measure the energy without destroying the compound beam – for example, we can reflect the beam from the moving mirror and measure the blow-back. Our description of the photon allows concluding that after this measurement of the energy it is impossible to provoke the interference between both components. Until the photon is partially in one and partially in another beam, the interference at beams overlapping can appear but this possibility disappears as soon as the photon is transferred by measurement into one of the beams".

Not being within the principle of superposition, we can ask ourselves another question: if the moving mirror is so light that the photon gives it a significant part of its energy and impulse, can it be that intermediate event that ruins the unity of the ends of its path, i.e. the relation between the source and the detector? After all, when reflecting from a moving mirror, the photon must give it a part of its energy and impulse, and change, which can be interpreted as an absorption of the primary photon and birth of another photon with different characteristics.

In the book [1] they describe a range of experiments of searching the answer to the questions similar to Dirac's question about the moving mirror (here and further we quote the descriptions of the experiments mentioned in [1]):

In the experiment of Wang, Zou and Mandel [5] with changing the contrast of the interference pattern at changing the transparence of the filter, interpreted as the authenticity of the information about photon's movement path: *"They performed a range of beautiful experiments to observe the optical interference, where, if changing the transparence, it was possible to constantly change the authenticity of the available information about the photons movement path.… The curve A, obtained at total absence of information about movement path, demonstrates an utterly clear interference pattern. Vice versa, the curve B, obtained with whole information about movement path, demonstrates total absence of interference pattern"*.

The same is the interpretation of the results of the experiment shown in Anton Zeilinger's article [6]: *"The states of two photons that appeared at split of one photon in nonlinear crystal were mixed up by impulse. One of the photons from EPR pair was transmitted through the double slit on the detecting screen, and the second – through the lens on detector which placement could be changed. When this detector was placed into the focal surface of the lens, and the placement of the second photons of EPR pair could not be determined, the first photons, going through the double slit, demonstrated the interference pattern. But when the placement of the detector was changed and it could determine the placement of the second photon, the interference pattern disappeared. This experimental result gives evidence that we not only do not need to observe the trajectory of the interfering particles for the interference pattern to disappear, we also do not need to know through which slit the particle has gone. The possibility to know it is enough"*.

"In the article there is an even more astonishing experiential result. There is an image where we see the interference pattern created by the second particles of the EPR pair, which did not go through the double slit! These particles somehow "learnt" not only that the first particles of the pair went through the double slit but also the geometry of these slits".

The results of these outstanding experiments can really seem astonishing from the viewpoint of superposition principle and built on it orthodox quantum mechanics. However, they can cease being astonishing if we address to Dirac's question about the moving mirror and our attempt to answer it.

In both described experiments to change "the availability of trustworthy information about photon's movement", they change the scheme of experiment, which change the conditions of the connection of the source and the detector of photons. These are purely physical changes, capable to influence significantly the photon's movement, which, according to the proposed approach, is defined exactly by the conditions of the connection between the source and the receiver of the radiation.

If we look at these changes from the standpoint of a possibility or impossibility of obtaining any information, we immediately come to a number of further questions on whether this information was actually obtained, etc. The proposed approach excuses us from this necessity.

4. Other experiments with photons described in the book "The Quantum Challenge"

The experiment of Grangier, Roger and Aspect with singular photons and beamsplitter [7]. The photon after the beamsplitter goes by two paths and gives interference after reunion – totally according to the mental experiment of Dirac described above. And with the same comments.

The experiment with the postponed choice [8], where the results of the experiment happened to not depend on the moment of changes in the experiment's scheme – before or after the light impulse passes through the first beamsplitter in Mach-Zeinder interferometer: *"The experiment with postponed choice shows the insufficiency of the simple wave-particle interpretation.… We have a task to create a new conception that will be fundamentally different*

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from the beliefs that came from the world of classical physics".

However, according to the proposed model "the postponed choice" should not influence the result of the experiment, because the "choice" is made at the moment, when the photon leaves the source, that corresponds (for the photon) with the moment of getting in the detector.

Pfleegor-Mandel experiment. Two lasers – one photon [9]. The light from two lasers, turned by small angle, falls onto the screen (detector). We see the interference pattern:

"The idea of light as a wave can easily explain this result: the waves, formed in two lasers, interfere with each other. But Pfleegor and Mandel made an important change in this experiment. They decreased the intensity of the light source, so only one photon could most likely be simultaneously present in their experimental equipment. But in this case as well they discovered weak but doubtless manifestations of interference".

"In this experiment the lasers radiate photons in different moments of time and only one of them radiates in a defined moment!"

Here the described results also agree with the proposed model. If the wave appears along all the way of the beams at the same moment of their time, this experience is equivalent to the experiment of Grangier, Roger and Aspect with beamsplitter [7], but the splitting happens in the opposite direction. However, as for the photon the moments of radiance and of getting to the detector is the same one moment, the direction is indifferent for the photon.

The mentioned above authors' comment that the lasers radiate photons in different moments of time is based, evidently, on the a priori guess that each source radiates the photons independently from each other. From the studied model's standpoint, this assumption is wrong. We can assume that all of it happens at the same moment of the own time of the electromagnetic wave, that connects both sources with the radiation detector. The moment when the atom of the detector receives the portion of the electromagnetic wave' energy, which we call a photon, and both sources of the electromagnetic wave give their inputs into this portion.

5. Photon as interactions transmitter

Let us imagine the point source of electromagnetic waves, radiating waves in all the directions. Let one photon's energy hv radiate. The detector, being a spherical screen of a very big radius, registers the absorbing of the photon in one point of the screen.

Interpretation of this event from the orthodox quantum mechanics standpoint: wave function collapse, information transmission from some areas of the photon to others with superlight speed, etc.

Interpretation from the studied model standpoint: the photon appearing in the source and the screen's atom that registered it at the same moment of its own time represents the interaction of the source with one of the points (atoms) of the screen.

Here we are having this question again – how from a great amount of atoms the one which takes part in the interaction is chosen? We can assume that the factors influencing the choice are the intensity of the electromagnetic wave field in the point of atom location, and also the correlation of electromagnetic waves and individual characteristics of the atom. We can also assume that if at the moment the electromagnetic wave does not have the required correlation with neither of the screen's atoms, the taking off of the photon can be postponed till the moment when this correlation appears.

We can consider the photon filling out the space inside the screen, regardless its size, but nothing follows out of it except for the fact that the only function of this photon is the reciprocity of the source atom with the screen atom that corresponds the most to the parameters correlation.

Let us note that this statement fully corresponds to the modern classification of the microparticles (the Standard Model of particle physics), according to which the photon belongs to the elementary bosons, which are considered force carriers. So, the studied viewpoint on a photon correlates to the standard model of microparticles viewpoint, allowing to explain a whole range of experimental facts that are formally described by the mathematical apparatus of the quantum mechanics, but do not find a satisfactory explanation when looking at the photon only as a quant of electromagnetic radiation.

6. Conclusions

We believe that the solution of the modern physics' problems mentioned above requires the exclusion of the contradiction of the used notions, which can be regarded as one of the ways to find adequate means to describe the world, which is, as Einstein insisted, necessary [10].

Concluding the described in this work interpretation of experiments with the photons we can assume that at least some of these notions are already found.

One of them, found by Einstein himself in the very beginning of the new physics era – the notion of the special relativity theory about transformation of the time in different coordinates, from which it follows that the lifespan of the light in its own coordinates is always equal to zero. We believe that this important consequent of Einstein' s theory is undeservingly undervalued, as the examples mentioned above show the important role of the electromagnetic radiations in the formation and properties of time-space.

The second – the notion of bosons as interactions transmitters that is the modern basis of the standard model of microparticles.

And the third – the notion that the space and time are nothing more that the forms of interaction and change of the matter, existing in the world literature since Aristotle, and in different ages making the basis of the physical worldview of such famous scientists as Leibnitz, Mach, Narlikar and others [11]. The value of this worldview on the space and time is that it, not rejecting the notions "space" and "time", allows to realize their secondariness in relation to the structure and movement of the matter. And that also means realize the possibility of their special manifestations in special conditions created by physicists in their experiments on researching the microworld. Not asking from us to refuse the main notions: causality, reality, *"possibility to objectively describe a separate microsystem"*, that the great Einstein was insisting on all his life.

We hope that the joint application of the notions mentioned above could be enough to explain the big amount of the experiential data, inexplicable from the orthodox quantum mechanics standpoint. Which brings it to the sad conclusions about essential impossibility to understand and explain it.

An attempt to apply to the photon the requirement to eliminate the contradiction of the notions allows us making one more generalizing comment. On one hand, the photon is a portion (quant) of a well studied electromagnetic radiation, spreading in the space with a light speed. On the other hand, it is a transmitter of interactions with its own zero lifespan. And it is the same physical phenomenon. The relativity theory does not only give us a possibility to calculate the correlation between physical characteristics of the interacting objects in the coordinates of each of them, but also shows that in every of these coordinates the interaction may look and be perceived differently. And an adequate viewpoint on every interaction act must be based not on the opposition but on the combination of its descriptions from the standpoint of every interacting object.

Einstein already in his first paper on relativity in 1905 pointed to a fundamental change in the spatial relationship while driving at the speed of light: «At v = V all moving objects, observed from the «stationary» system became flat and turn into plane figures» [12], §4 (where v - the velocity, V - the speed of light).

Hence it follows directly that for the beam of light (photons) the depth of the space in the direction of motion and all distances in that direction are always zero, regardless of the values in our coordinate system. And that the consequences described above are derived from the very foundations of the theory of special relativity. What gives us the basis for a shift of attention from the question of "reality" and "unreality" of the observable world to the need for a deeper understanding of the theory underlying the theoretical physics for over a hundred years.

References:

1. George Greenstein, Arthur G. Zajonc (Amherst College). The Quantum Challenge. Modern Research on the Foundations of Quantum Mechanics. Jones and Bartlett Publishers. 2006. (Russian edition).

2. A.Einstein. Elementare Oberlegungen zur Interpretation der Grundlagen der Quatten-Mechanik. In "Scientific Papers, presented to Max Born", 1953, Edinburgh: Oliver & Boyd, 33-40 (Russian edition).

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3. Kudriavtcev Iu. Once again about Einstein's realism: the matter waves and Bell's inequalities from the point of view of the special theory of relativity // Physical Interpretation of Relativity Theory: Proceedings of International Meeting. Bauman Moscow State Technical University, Moscow, 29 June–02 July 2015. – Moscow: BMSTU, 2015. Pp 266-275.

(http://www.pirt.info/scopus/all-issues/2015/articles/Kudriavtcev2.pdf),

(arXiv:1504.07938 [physics.gen-ph]).

4. Dirac P.A.M. Scientific Papers Collection. V.1. Quantum Theory (monographs, series of lectures) / Ed. A.D. Sukhanov. – M.: FIZMATLIT, 2002. (The Principles of Quantum Mechanics. Chapter 1. Principle of Superposition. Pp. 17-31).

5. Wang L.J., Zou X.Y. and Mandel L. Induced coherence and indistinguishability in optical interference. Phys. Rev. A. Vol. 44. Pp 4614-4623, 1991.

6. Zeilinger Anton. Experiment and the foundations of quantum physics. Rev. Mod. Phys. Vol. 71. Pp. 288-297, 1999.

7. Grangier P., Roger G. and Aspect A. Experimental evidence for a photon anti-correlation effect on a beamsplitter. Europhys. Lett. Vol. 1. Pp. 173-179, 1986.

8. Hellmuth T., Walter H., Zajonc A. and Schleich W. Delated-choice experiments in quantum interference. Phys. Rev. A. Vol. 35. Pp. 2532-2541. See also Alley C.O., Jakubowicz O., Steggerda C.A. and Wickers W.C. A delayed random choice quantum mechanics experiment with light quanta. Proceedings of the International Symposiumon Foundation of Quantum Mechanics – Tokyo. Edited by Kamefuchi. Physics Society of Japan Pp 158-164. 1983.

9. Pfleegor R.L. and Mandel L. Interference of independent photon beams. Phys. Rev. Vol. 159. Pp. 1084-1088, 1967.

10. A. Einstein. Einletende Bemerkungen uber Grundbegriffe. In "Louis de Brogile, physicien et penseur", Paris, 1953, p.4-14. (in Russian Edition: Альберт Эйнштейн. Вводные замечания об основных понятиях. Собрание научных трудов. т.III, М., «Наука». - 1966. С. 623-625).

11. Yury Vladimirov. The nature of space and time: anthology of ideas. Moscow, 2015.

12. A.Einstein. Zur Elektrodynamik der bewegter Körper. Ann. Phys.,1905, 17, 891-921. (in Russian Edition: Альберт Эйнштейн. К электродинамике движущихся тел. Собрание научных трудов. т.I, М., «Наука». - 1966. с. 7-35).