About the EPR paradox. Resolution features[1)]

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When interpreting the results of A. Aspect's experiments, bumped two concepts - quantum mechanics and relativity-were encountered, which requires a thorough consideration of the causes of the contradictions. Many works by different authors are devoted to the analysis of these issues, and the points raised here have also been repeatedly exhibited for analysis. However, it seems to us that it is necessary to address once again the key points of the contradiction and, if possible, in a compressed form.

Theory of relativity[7]

It is quite incorrect to talk about the *constancy* of the speed of light, knowing that the light is deflected in the gravitational field of the Sun. This empirical fact is not in doubt. Moreover, in the theory of relativity, the value of the coordinate velocity of light is quite arbitrary and its value depends on the choice of the reference system. The "law of addition of speeds" has ceased to be the law, and the rule of addition of speeds is defined by specific formulas of transformation of 4-coordinates. The invariant of the speed of light remains only in the history of physics and nothing more, and the second postulate of Einstein takes the form of the principle of local Lorentz invariance and is an integral part of the General principle of equivalence. All this is due to the fact that 3-velocity (macro-) has lost the property of covariance and therefore the ability to be a standard of measurement of space-time relations.

Thus have:

- ☞ to speak about the spatial constancy of the value of the speed of light in the sense of its physical measurability with the help of a relativistic standard does not make much sense, and about the property of maximality ─ even more so. Just the standard loses its attributive property ─ immutability;
- ☞ to speak about the value of the speed of light in the nonlocal sense, that is, in the integral sense, also does not make sense, because there are the same difficulties as for the majority of integral quantities in GTR. We can only talk about its local value (at a point);
- ☞ the principle of constancy of the speed of light (second postulate) reliably takes the form of local symmetry in transformations of point events.

The certainty of the concept of locality in connection with the space-time relations, it would seem, should be manifested in the micro-scales of quantum physics. It turned out, there it is not.

Quantum mechanics[6]

Lorentz local invariance becomes one of the symmetry point transformations already *abstract* space-time point events, which, generally speaking, is not a place in quantum physics. Just there are no prototypes for them ─ and therefore abstract. In addition, the "topological linkage " between continuous space and continuous time - the velocity defined as a derivative coordinates by the time lose sense, since the result of this operation (the calculated velocity) turns out to be a non - commuting value with the initial coordinate. But that's absurd! There is a question of the need to abandon the use of the notion of derivative in the definition of evolution.

To abandon operations of differentiation and integration of space-time characteristics, that is, operations with their infinitely small values? Perhaps, for quantum physics this is possible, because in the manner of solving Heisenberg's equations, it is possible to replace the time differentiation operations with bracket algebraic switches, moving from methods for solving differential equations by mathematical

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1) **I beg your pardon for my not very good English!** The original text in Russian**:** http://vixra.org/pdf/1804.0356v1.pdf

analysis to the dynamic algebra of physical observations to find the evolution of the system. This is how we can hope for the possibility of transition to the description of evolution by means of algebraic methods.

The situation related to entangled photons emitted from one source has a characteristic relativistic feature due to the fact that the events associated with this photons are "simultaneously" space-like and time-like, which makes it impossible to establish the causation of these events. Therefore, *the specific macrotimes and macrodistances associated with the photons of the Aspect's experiments as integral characteristics and calculating from of the point characteristics of the local Lorentz-invariance principle, strictly speaking (metrically), cannot be "predicates" of the causality principle in the "local execution".*

General summary

The continuation of the EPR paradox solution should be algebraic, but not traditional topological. There is a hope that in this case the local causality will cease to be such a "sick" question!

A mental experiment of the EPR and the new Aspect's reality

Phenomenology

Coordinate and momentum describe fragments of reality as they represent properties of a real object. The Heisenberg uncertainty relation does not allow their joint measurement (better to say – these characteristics cannot coexist). However, quantum mechanics only States the impossibility of joint measurement of non-commuting values: the measurement of one of them makes uncontrollable changes to the other. Since we are talking about the effect of measurement of one quantity on the behavior of another, and even on the fundamental incompatibility of the joint existence of their values, the full theory should be able to describe the mechanism of the influence of one on the other. However there is nothing description such an influence in quantum mechanics

According to Einstein, the conclusion: *quantum mechanics either gives an incomplete description of reality or its interpretation is incorrect, since there is no description of the mechanism prohibiting the joint measurement of the coordinate and momentum.*

To strengthen the argument of the EPR group, one can propose a mental experiment of this type.

Suppose that at a point with *known coordinates* a certain particle splits into two flying in opposite directions. When the particles have spread over a sufficient distance, they are exposed to detection and measurement of their pulses. The *momentum of the initial particle* is calculated from the measurement results. Thus, we managed to bypass the principle ban of Heisenberg uncertainty relations on the joint measurability of the coordinate and momentum. For the initial particle, we measured the momentum, though "retroactively" but in conjunction with the coordinates. The coordinates of the initial particle were known in advance. The law of conservation of momentum helped us.

To satisfy to the uncertainty principle, we can assume (according to Einstein) the existence of elements of some reality describing by hidden parameters of the interaction of particles, which will not allow us to accurately measure the pulses together with the coordinates but, most importantly here that that the distance between the particles is not regulated, which means the hidden interaction can have any velocity of propagation.

EPR conclusion: *in quantum mechanics there is an alternative, which involves the adoption of one of two – incomplete description or nonlocality of interaction.*

Specific studies in this direction are connected with the theoretical work of Bell and the experiments of Aspect.

Briefly of the essence of the Bell's conclusions. For dichotomous (having only two values) of a variable with a fairly arbitrary function of probability distribution was derived for overall inequalities (Bell's). Similar formulas were derived for the dichotomous observables described by quantum theory. It turned out that the quantum mechanical relations violated Bell's inequalities.

The essence of the Aspect's experiments. As a dichotomous variable, Aspect chose photon polarization and ultimately experimentally confirmed Bell's theoretical results. The essence of these confirmations was to register a correlation between the polarizations of two photons, and in the form of a mental experiment with momentums, we can talk about the existence of a correlation between the pulses of particles, the analogue of which, perhaps, does not allow to violate the Heisenberg uncertainty principle.

Conclusion: *as a result, instead of the "elements of reality by Einstein", needed for explain the mental experiment of EPR, one has quite and undoubtedly manifested himself as a" new reality " of quantum possibility, both theoretically and experimentally*. The question arises: what next, what can be done with it?

The states of systems the so-called entangled particles play an important role in the resolution of the issues raised, and the analysis of their behavior leads to very non-trivial consequences, the conclusions of which can be used for technological purposes for information transfer. To understand how systems entangled particle are conceptually constructed, let us consider an example of obtaining a solution for a pair of photons in an Aspect's experiment.

Let us consider how the solution of the wave equation for a two-photon system is obtained.

Since photons do not interact, the equation for a closed two-photon system allows for the separation of variables for both particles, which makes it possible to present two independent solutions for each photon using the same state vectors $|\psi\rangle$, since photons are in identical States, although with different parameters.

Denote the vector of the first photon as $|\psi\rangle_1$, of the second as $|\psi\rangle_2$. It should be noted that although $|\psi\rangle_1, |\psi\rangle_2$ belong to the same type (one-particle) of Hilbert's spaces, however these spaces are different. Therefore, the state vector of a two-particle system must be written in the form

$$|\Psi\rangle = |\psi\rangle_1 \otimes |\psi\rangle_2 \,. \tag{1}$$

This vector already belongs to the two-particle Hilbert space.

In the coordinate representation the vectors are represented by wave functions. Let $\psi_{1,}\psi_2$ be wave functions corresponding to the first and second photons. Taking into account that the wave functions are defined with the accuracy up to the factor modulo equal to one, we present these functions in the normalized form, having allocated explicitly spatiotemporal and phase dependences:

$$\psi_1 = \psi_1(x_1, y_1.z_1, t_1)e^{i\varphi_1}, \quad \psi_2 = \psi_2(x_2, y_2.z_2, t_2)e^{i\varphi_2}. \tag{2}$$

States described by vectors or wave functions are called *pure* states.
According to (1), the general solution of the wave equation for a two-particle system is presented as:

$$\begin{gathered}\tilde{\psi}(x_1, y_1.z_1, t_1, \varphi_1;\ x_2, y_2.z_2, t_2, \varphi_2) = \\ = \psi_1(x_1, y_1.z_1, t_1) \cdot \psi_2(x_2, y_2.z_2, t_2)e^{i(\varphi_1+\varphi_2)} = \tilde{\psi}e^{i\chi}.\end{gathered} \tag{3}$$

The wave function of a pair of photons as bosons must be symmetric with respect to the permutation of particles. To meet this requirement, we must perform the operation of the symmetrization of the solution found after the separation of variables and obtain a solution in the form of a product of the wave functions of photons. Then the wave function Ψ for the two-photon system takes the form:

$$\Psi = \frac{1}{\sqrt{2}}\{\tilde{\psi}_1 e^{i\chi_1} + \tilde{\psi}_2 e^{i\chi_2}\} = \frac{1}{\sqrt{2}}\{\tilde{\psi}_1 + \tilde{\psi}_2 e^{i\delta}\} e^{i\chi_1}. \quad (4)$$

In connection with the transition from one-particle descriptions (2) to the complete description (4), something happens that is called the loss of photon individuality with the fixation of the phase ratio between the incoming wave functions of photons. Here, in (4):

first, the wave function Ψ is symmetric with respect to the permutation of photons

second, the phase factor δ becomes an internal characteristic of a two-photon system, which must now be considered as a pair of coherent photons regardless of where the first is and where the second is.

It is the *coherence*, that is, the rigid fixation of the phase difference δ, and gives the effect of the confusion (bond) of photons. Their general symmetrized wave function Ψ itself remains defined up to a new phase factor modulo one $- e^{i\chi_1}$, where χ_1 can already take arbitrary values, since the coherence of the photons that make up the system is fixed by the phase δ.

However, the intraphase bond of δ remains constant until the integrity of the system is destroyed by the phase mismatch between the photons entering the system and these components acquire autonomy and independence of existence. This process is naturally called *decoherence.*

In the nondestructive system (the system of tangled coherent photons (4)), each photon can no longer be represented by a pure state, as standard described by a vector or a wave function. Its description is possible only with the help of so called *density matrices* – description, which is more general in the discipline of quantum mechanics. The states described by density matrices are called *mixed* states.

The characteristic difference between mixed States and pure States is the following: the entropy of pure states is zero, the entropy of mixed states is determined by the formula

$$\Xi = -\overline{(\ln M)} = -\mathrm{Sp}(M \ln M), \quad (5)$$

where M is the density matrix of the system. The value of entropy becomes zero in the case of a pure state, and only in this case. Non-zero value of the entropy of the mixed state means that such systems have information capacity (according to Shannon). Because of this, it is through the modulation of the phase δ in the total of the system the entangled coherent particles, it is possible to try and implement the ability to transmit data.

D. Greenberger proposed the principles of information transfer based on the two-photon model in 1998[1]. More information can be found in [2]. The most natural is the use of many-particle systems of entangled particles. The proposed use of a three-photon system justifies Raymond W. Jensen in [3]. The paper [4] presents a specific calculation of the entangled states for a two-photon system.

One can understand the essence of the attempt to transmit information using, for example, a three-photon system of entangled States by referring to the work [3] . To begin with, we note the features of the relativistic background on which the experiment is based.

Technology

What are the features of experiments with photons?

1. A photon is a relativistic object. All events associated with the movement of several photons from a single source can be considered as time-like and space-like. The first allows us to consider these events as occurring at one point, that is, as locally and causally related; the second - as simultaneous and nonlocality, but causally unrelated. However, the movement of photons occurs in a specific frame of reference and the events are really separated both spatially and in time. That is, locality/nonlocality, causality/not causality - it is "all in one". In these states, generally speaking, there is no past, no future, no near, no far, although in a particular frame of reference there is the first, the second, the third and the fourth. The quantum theory connects them into one whole with the help of entangled States of several particles, each of which can be registered by its detector as a separate object.

2. Entangled quantum objects, as a whole, can be described as pure states, that is, with the help of wave functions. The components that make up this entangled integrity sub'objects and called "particles" can not be described by wave functions. They are described by density matrices. The main feature of the description of States with the help of density matrices is their nonzero entropy, which means that this object has information capacity. This gives a fundamental opportunity to exchange information between objects that are part of the integrity.

3. A photon is a quantum object and has a dichotomous property – "polarization". The same property has a monochromatic beam of light (apparently, this is one of the few properties in classical physics, subject to real quantization). On this basis, experiments with light can adequately simulate the behavior of photons with respect to their polarization.

4. In experiments with entangled photons, in view of the foregoing, the judgments of Bob with Alice about the causality of events connected with entangled photons, can be totally inappropriate. For example, if Alice and Bob are placed in the pencil case's and pencil's frames of the paradox of the same name [5], they will never be able to agree. In the problems of analysis of events related to the spread of photons, their situation is aggravated by the fact of the zero value of the interval, that is, the unity of spatial and temporal similarity of events.

The principle of information transmission in the three-photon system FTLC

The FTLC-device[2)] proposed in [3] is shown in Fig.1. The triplets of entangled photons propagate in the plane with the normal N as shown in the figure and are emitted by the source S and descend. The Sender is on the right, the Receiver is on the left. The Receiver has two photon receivers.
For any triplet emitted from S, the Sender receives one photon and chooses either polarization measurement or information erasure. The Receiver, meanwhile, receives two photons and performs a comparison of the correlations according to the type of Aspect's experiment. The difference in correlation statistics is the basis for the FTLC.

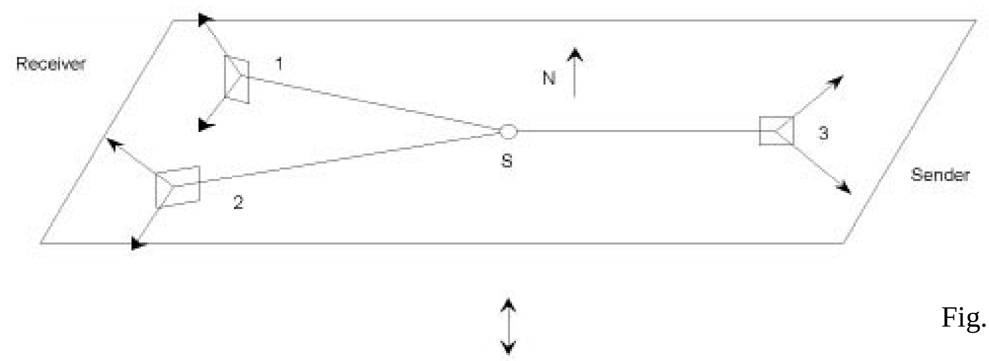

Fig. 1

2) Faster-Than-Light or superluminal Communication

It should be noted that the authors [2] do not reject the idea of Greenberger, who first put forward the idea of superluminal transmission, but only point to possible technical shortcomings in the implementation of the concept. Meanwhile and in their argument there are obvious incorrectness connected with non-accounting of features of a relativistic background on which experiment in photon execution is planned[3] (see notes 3, 4, 5, 6) in this connection we also stopped in more detail in the previous section.

Links

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V.A.Kasimov. *About the EPR paradox. Resolution features.* (English version)

Abstract
In interpreting the results of experiments A. Aspect faced two concepts of quantum mechanics and relativity theory, which requires a thorough consideration of the causes of contradictions. The analysis of these issues devoted many works of different authors, and the points raised here also have been exhibited for analysis. However, we feel that contact again to the key moments of the contradiction and possibly in compressed form is a must.

[3]) See notes 3, 4, 5, 6 in https://www.academia.edu/32443465/