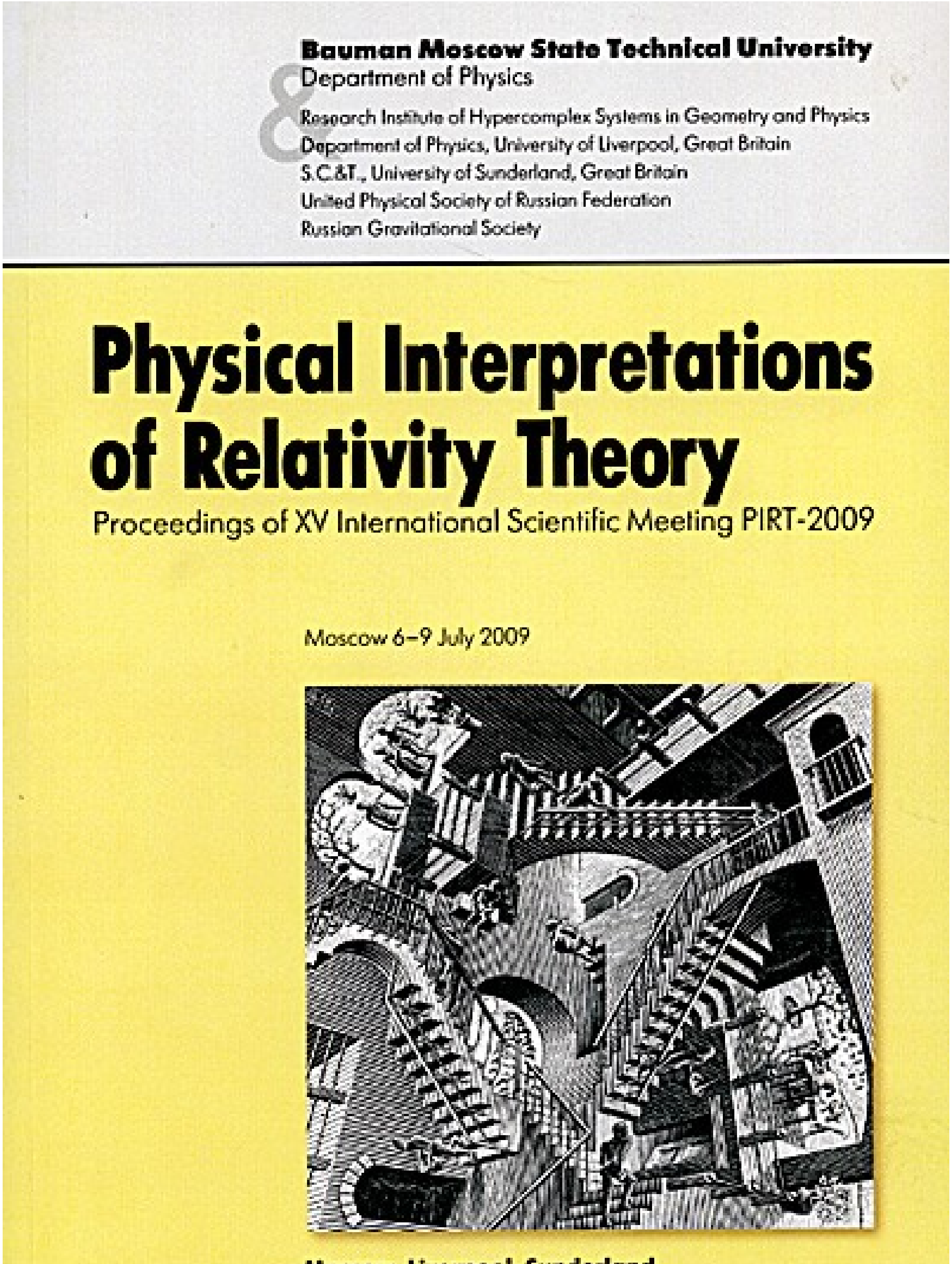


Physical Interpretation of Relativity Theory: Proceedings of International Meeting. Moscow, 6 – 9 July 2009. Edited by M.C. Duffy, V.O. Gladyshev, A.N. Morozov, P. Rowlands. – Moscow: BMSTU, 2009. - 472 p. (pp 431 – 437).
ISBN 978-5-7038-3394-0

Everettica and general theory of relativity

Y.A.Lebedev, BMSTU.

The modern international encyclopedic dictionary "Global studies" gives such definition of everettica: « Everettica - area of the spiritual activity directed on comprehension and description of many-worlds as a fundamental characteristic of life. Was named after American physicist Hugh Everett III, who offered in 1954 - 1957 a revolutionary treatment of quantum mechanics according to which many-worlds (multivers) is a full physical reality » [1, p. 1013]. Development of everettica into an independent scientific discipline has been recently reviewd [2].

As can be seen from this definition, everettica encompasses wide range of studies. It's foundation is a physical theory of many-worlds formulated by H.Everett in 1954 - 1956 and published in 1957 [3]. Right in the first paragraph of this seminal work, Everett formulates the general goal of his study: «The task of quantizing general relativity raises serious questions about the meaning of the present formulation and interpretation of quantum mechanics when applied to so fundamental a structure as the space-time geometry itself. This paper seeks to clarify the formulations of quantum mechanics. It presents a reformulation of quantum theory in a form believed suitable for application to general relativity » [3, 454].

As we see, everettica is "genetically" bound with general relativity and, in its physics part (everettism) is nothing else but an attempt to reconcile general relativity and quantum mechanics.

So what did Everett consider as the main complications in this task? Here is what he wrote about that: «How is one to apply the conventional formulation of quantum mechanics to the space-time geometry itself? The issue becomes especially acute in the case of a closed universe.3 {3 See A.Einstein, The Meaning of Relativity (Princeton University Press, Princeton, 1950), third edition, p. 107.} There is no place to stand outside the system to observe it. There is nothing outside it to produce transitions from one state to another. Even the familiar concept of a proper state of the energy is completely inapplicable. In the derivation of the law of conservation of energy, one defines the total energy by way of an integral extended over a surface large enough to include all parts of the system and their interactions.4 {4 L.Landau and E.Lifshitz, The Classical Theory of Fields, translated by M.Hamermesh (Addison-Wesley Press, Cambridge, 1951), p. 343.} But in a closed space, when a surface is made to include more and more of the volume, it ultimately disappears into nothingness. Attempts to define a total energy for a closed space collapse to the vacuous statement, zero equals zero.

How are a quantum description of a closed universe, of approximate measurements, and of a system that contains an observer to be made? These three questions have one feature in common, that they all inquire about the quantum mechanics that is internal lo an isolated system » [3,455].

It is obvious, that the mere concept of the truly isolated system is a meaningless abstraction. The closest object one can imagine is Universe, one of the major objects considered in general theory of relativity. To describe truly isolated systems and resolve the problems stated above Everett proposes a concept of «relative state», and then states that «The mathematics leads one to recognize the concept of the relativity of states, in the following sense: a constituent subsystem cannot be said to be in any single well-defined state, independently of the remainder of the composite system. To any arbitrarily chosen state for one subsystem there will correspond a unique relative state for the remainder of the composite system. This relative state will usually depend upon the choice of state for the first subsystem. Thus the state of one subsystem does not have an independent existence, but is fixed only by the state of the remaining subsystem » [3,455].

Measurement-wise the concept of "relative state" requires observer to be one of poles of this state. So the observer transforms from an optional element of physical systems, as it perceived in the classical physics and in Copenhagen interpretation quantum mechanics, into an integral element of any physical interaction, and this way enters quantum mechanics and general relativity theory.

Concept of the observer is one of the key concepts in everettica. Everett introduces it in general form «as purely physical systems» [3, 457]. However, it later turns out that the observer-machine (in physical experiment) can posses some subjective properties. «In fact, all of the customary language of subjective experience is quite applicable to such machines, and forms the most natural and useful mode of expression when dealing with their behavior, as is well known to individuals who work with complex automata » [3,457].

Extended Everett's Concept (EEC) of M.B.Mensky, later development of everettica, [4] accepted that this subjective property can be identified as consciousness (more precisely, as everettical consciousness) of the observer. Idea of everettical consciousness follows from concept of everettical memory which is defined as follows: «When dealing with a system representing an observer quantum mechanically we ascribe a state function, ψ^0, to it. When the state ψ^0 describes an observer whose memory contains representations of the events *A,B, ...,C* we denote this fact by appending the memory sequence in brackets as a subscript, writing:

$$\psi^0_{[A,B,\ldots,C]} \tag{9}$$

The symbols A, B, …, C, which we assume to be ordered time-wise, therefore stand for memory configurations which are in correspondence with the past experience of the observer »[3, 457].

Everettical consciousness is an ability of objects possessing memory to record in this memory changes of their state and state of environment, occurring as resulting from interactions between such objects and their environment.

As a result of interaction between observer and quantum reality (QR), called in everettica the «Crystal of Mensky», and recording this interaction result in memory of the observer "Classical Realities of the Physical World" (CRPW) arise. Depending on the exact number of eigen values of ψ -function and the corresponding operators of the respective physical values describing interacting systems, different number of CRPW might arise. Combined these CRPWs form a multitude called in everettica an «altervers» [5, 486].

The difference between everettical consciousness and mind should be emphasized («… The principle of intelligence; the spirit of consciousness regarded as an aspect of reality … The faculty of thinking, reasoning, and applying knowledge» [6]). Everettical consciousness and mind function in different types of realities. The first one in CRPW of altervers, while the second one – in comprehended realities (interpreting realities) (IR) of intelligent subject existence.

From the scientific and philosophical perspective, the most important idea is the one of equivalence of all realities ontological status, introduced by Everett «The whole issue of the transition from "possible" to "actual" is taken care of in the theory in a very simple way — there is no such transition, nor is such a transition necessary for the theory to be in accord with our experience. From the viewpoint of the theory all elements of a superposition (all "branches") are "actual," none any more "real" than the rest. It is unnecessary to suppose that all but one are somehow destroyed, since all the separate elements of a superposition individually obey the wave equation with complete indifference to the presence or absence ("actuality" or not) of any other elements. This total lack of effect of one branch on another also implies that no observer will ever be aware of any "splitting" process » [3, 459-460].

The last sentence of this explanation has generated persistent myth, that Everett theory is not verifiable, and therefore can not be adapted to scientific consideration. This misconception is based on superficial interpretation Everett's ideas. In this context Everett refers primarily to observer's self-assessment, and not at all means physical impossibility of "branches of realities" observation.

This erroneous view however proved to be persistent and had negative effect on physical everettism. We will therefore pay special attention to the cases where phenomena of many-worlds was exhibited so patently, that it can overcome deleterious misinterpretation of the theory – at least for those who is ready for unbiased consideration of experimental facts.

Theoretical treatment of interaction between everettical branches of realities has been suggested already in 1989 by Markov end Muhanov [7], later, in 2000, were deemed inevitable consequence of primary everettical processes of splitting and were named «sklejka» («gluing») [2, 106 - 108]. In more details processes of this type were considered from the quantum-mechanical perspective in publications [8] and [9].

This theoretical treatment of "splitting - sklejka" mechanism provided for new interpretation of interference. The first everettical explanation of interference has been given by Deutsch [10].

Let's first critically review the description of processes taking place in an interferometer, as it is given by "Copenhagen interpretation" of quantum mechanics.

Consider the scheme of a quantum interferometer (fig. 1) [11]:

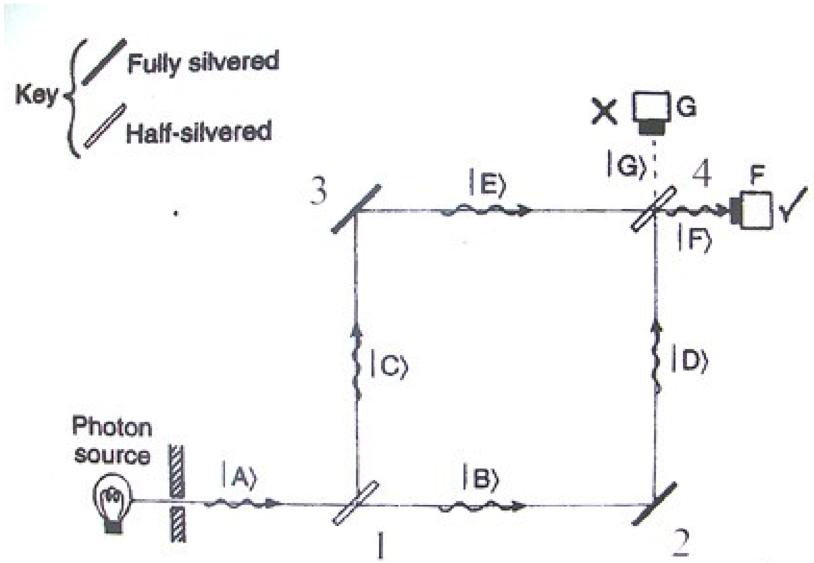


Figure 1. Quantum interferometer. Photon source - a source of photons; Fully silvered - completely reflecting mirror; Half-silvered - a translucent mirror («a divider of photons»); G and F - detectors of photons.

It was experimentally shown, that even «single photons» passing through this setup never evoke any response on detector G.

Traditional quantum mechanics offers a description of the processes of photons propagation through the system of mirrors 1 – 4, and also explains the permanent passivity of detector F through the idea of corpuscular-wave dualism, by ascribing wave properties to the photon. Roszkowski explains this:

« A ray of light incident on a half-silvered mirror will split into two rays, where each ray is half the intensity of the original ray.

The quantum mechanical description of a single photon is that at the mirror the photon wavefunction ψA splits into two components:

$$\Psi_A \to \sqrt{\frac{1}{2}}(\Psi_B + i\Psi_C)$$

The factor of i arises for the reflected component, because there is a one-quarter wavelength shift upon reflection. (The factor of root-two is a normalization factor.) This superposition seems to imply that the photon goes in both directions simultaneously.

However, if we measure what happens to a single photon incident on the mirror by placing detectors at 1 or 2 we would find that it went in one of either direction. Quantum mechanically this is because the measurement has caused ψA to collapse into one of its components, namely ψB or ψC.

Now consider an interferometer where the photon path is split at 1, and then brought together again at a half-silvered mirror at 4. We can show that because of interference effects detector G will not detect any photons …

$$\Psi_A \to \sqrt{\frac{1}{2}}[i\sqrt{\frac{1}{2}}(i\Psi_F + \Psi_G) - \sqrt{\frac{1}{2}}(\Psi_F + i\Psi_G)] \to -\Psi_F$$

The probability of detector G measuring the photon is thus zero » [11].

This explanation inevitably rises a question about the essence of wave function division on the mirror 1, the mechanism of "loss" of a quarter of wavelength of «a wave photon » and legitimacy of the description of this loss via the imaginary unity factor.

Roszkowski admits this problems and gives the following explaition: «You might object to the idea of the photon wavefunction being splitting into two paths, as it appears to imply that the photon itself is also split into two. But remember if this did not happen there would not be any interference effects, and the photon would then be measured with equal probability by detectors G and F. This outcome does not happen» [11].

This "merciful" explanation apparently takes roots in experiment and does not resolve the issues mentioned above, but contains the key phrase, which alleviates acceptance of many-worlds interpretation: «as it appears to imply that the photon itself is also split into two». Deutsch interpretation clarifies this vague «as it appears to imply» and ascribes splitting not to a photon, but to the universe as a whole. In other words, after interaction with the mirror 1 we have not a single photon, but two photons in two different branches of altervers. Note, that at that moment it’s not known which of these branches is «ours universe». After "simple" reflections on mirrors 2 and 3 (not causing splitting), both photons simultaneously hit the mirror 4. It seems that here the photon coming from the mirror 3, can cause splitting again, giving birth to two universes in one of which photon goes upwards, to detector G, and in another one it goes to the right, to detector F.

Why then detector G never works? Many-worlds interpretation gives two possible explanations.

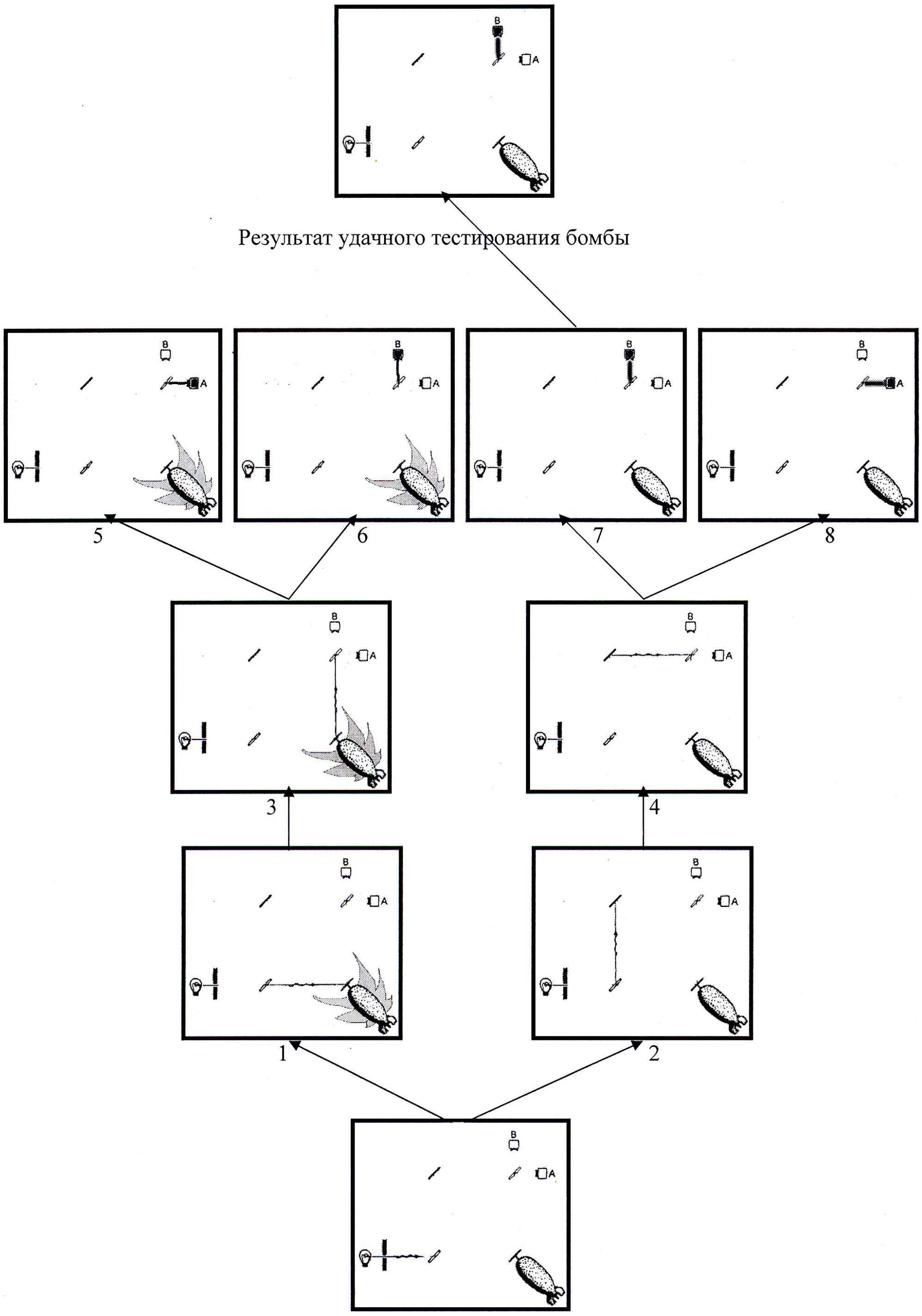
The first explanation refers to the fact that the same physical laws operate in two branches of the altervers, and this splitting is forbidden in many-worlds by the impulse conservation law. Upon reflection of the photon coming from the mirror 3 on the mirror 4 this mirror should get an downward impulse. However, the same time, it receives precisely same upward impulse from the photon coming from the mirror 2! Therefore, the total impulse of the mirror 4 equals to zero. The mirror is unaware of what photon transmits its impulse, the one which is "ours" or «from the parallel world ». Before the measurement, photons themselves "do not know" what world they are coming in. As a result the mirror 4 remains motionless, and the reflection does not occur. If detector G did generate any response, there would have been a violation of the impulse conservation law. Interferometer designed in such a way, that attempt to reflect a photon is always precluded by interaction of the mirror 4 with the other photon of the quantum superposition. This interaction between branches of altervers represents a type of the everettical sklejka. In wave-based description it referred to as interference.

The second possible explanation further develops the first one and reveals the details of the impulse conservation law implementation to this model. Let’s return to the Roszkowski line of argument. Note that in the last equasion an intermediate member contains wave functions Ψ_G and in such a manner that it indicates simultaneous presence of two photons in point G, one moving upward and another downward (members $i\Psi_G$ and $-i\Psi_G$). Since detector G is not a photons source, member $-i\Psi_G$ can only appear at such splitting in point G, if time is reversed in one of the arising branches of altervers. Physically it means that «total time» for photons in point G stops. Without time there is no movement and consequently there is no impulse also. Photons «drop out of time», and this state cannot be detected in any branch of altervers. Thus, point G becomes sklejka, being «an untimely trap» for the photon pairs formed at any upward reflexion of incident photons on the mirror 4.

A strong support of many-worlds interpretation of the interference comes from an idea suggested by A. Elitzur and L. Vaidman in their paradox of choosing an operational bomb from the collection of usable ones and duds [12]. The choice should be based on optical observation, and paradox comes from the fact that bomb detonator is so sensitive, that even a single photon triggers explosion. The experimental setup consists of the Mach-Zehnder interferometer which function we just considered from the traditional quantum-mechanical perspective. The bomb to be checked is placed in the interferometer instead of the mirror 2. In quarter of all operational bombs, detector B response is observed and "explosion" does not occur.

We can show that observation of detector B response without bomb explosion proves that bomb is operational in ours altervers.

Figure 2 presents the scheme of altervers splitting in Elitzur-Vaidman experiment.



Исходный момент впуска кванта в интерферометр с бомбой

Figure 2. Many-worlds treatment of the decision of problem of Elitzur-Vaidman.

Similar to the classical quantum interferometer, after a quantum enters the modified setup alterverses 1 and 2 are formed with equal, 50%, probability. The only difference is direction of their propagation after interaction with the first translucent mirror. In altervers 1 quantum goes to the right, while in altervers 2 it goes upwards.

As a result, bomb explodes in altervers 1, and in case of successful experiment, this is not «ours altervers».

Further reflections occur on fully reflecting mirrors, and altervers 2 transforms into altervers 4.

Altervers 4 (also with 50 % probability) gives rise to alterverses 7 and 8, differing in what detector (B or A respectively) senses the quantum on the interferometer outlet.

Altervers 8 is not interesting for us, as detector A in this altervers could respond even in case of broken detonator.

It is particularly interesting to consider altervers 7. There, Detector B responded. That could not have happened if there were no operational bomb in the interferometer. However, the quantum did not touch the mirror of a detonator, and the bomb did not blow up! This result became «our reality» because sklejka of «untimely trap» type is impossible between alterverses 6 and 7 - their physical configurations are very different. (In «the parallel world» which could have provided «a destructive interference», bomb explosion has destroyed mirror necessary for sklejka).

As a result, we only have one out of four alterverses benign for our experiment, i.e. probability of experiment success is 25% - precisely the experimental result obtained by international group of physicists lead by Kwiat [13], soon after the problem was first formulated.

This created foundation for new avenue of research in experimental quantum physics - Elitzur-Vaidman Interaction-Free Measurement (EV IFM).

Today EV IFM is a well developed field of experimental physics. Vajdman reviewed recent progress in the methods [14]. This publication gives outlook of conceptually new developments of EV IFM (mainly based on Zeno effect), which allowed for increase in probability of success in contact free detection of objects from 25 % up to 88 % .

Therefore, Elitzur-Vaidman effect is an experimentally proved everettical effect and as such, it disseminates misconception of «not verifiable» Everett theory. Hopefully, it will also stimulate further search of everettical effects in general relativity theory.

Considering weather his theory achieved the claimed «task of quantizing general relativity», H.Everett writes: «The" relative state " formulation will apply to all forms of quantum mechanics which maintain the superposition principle. It may therefore prove a fruitful framework for the quantization of general relativity. The formalism invites one to construct the formal theory first, and to supply the statistical interpretation later. This method should be particularly useful for interpreting quantized unified field theories where there is no question of ever isolating observers and object systems. They all are represented in a single structure, the field. Any interpretative rules can probably only be deduced in and through the theory itself » [3, 462].

Today, more then half a century after publication, principles formulated by Everett remain actual. Unfortunately, they are still not fully realized as for «interpreting quantized unified field theories» one have to have at least one such theory, possessing formalism developed enough to provide for introduction of "relative state" concept.

It is however clear, that recent «inner development» of everettica ensures fast and productive application of this discipline to the field and string models, which, empowered by the newest data on dark matter and dark energy, will update modern general relativity theory.

References

1. «Эвереттика», статья в кн. «Глобалистика (Международный междисциплинарный энциклопедический словарь)», М. – СПб. – Н.-Й., ИЦ «ЕЛИМА», ИД «Питер», 2006. – 1160 стр.
2. Лебедев Ю.А., «Неоднозначное мироздание», Кострома, 2000 г., 320 стр.
3. Everett Hugh, «"Relative State" Formulation of Quantum Mechanics», Reviews of Modern Physics, 1957, v. 29, №3, p.454 – 462.
4. Mensky Michael B. , «Postcorrection and mathematical model of life in Extended Everett's Concept», NeuroQuantology Vol 5, No 4, 363-376 (2007), **arXiv:0712.3609v1**
5. Шацкий А.А., Новиков И.Д., Кардашев Н.С., «Динамическая модель кротовой норы и модель Мультивселенной», УФН, май 2008 г., т.178, №5, стр. 481 – 488
6. The Free Dictionary by Farlex, **http://www.thefreedictionary.com/mind**
7. Марков М.А., Муханов В.Ф. «Классический предел в квантовой механике и предпочтительный базис», Труды ФИАН, т. 197, 1989 г., с 3-6., электронный вариант http://www.everettica.org/art/Markov_Mukhanov.pdf
8. Лебедев Ю.А., «Феноменологический формализм описания взаимодействующих ветвей мультиверса, мультивидуума и явления «склеек ветвей мультиверса»», «Математические структуры и моделирование», Вып 16, Омск, ОмГУ 2006, с. 59 - 66.
9. Лебедев Ю.А. «Нелинейные семантические аспекты квантовомеханической концепции "соотнесенных состояний" и перспективы развития эвереттики», «Математические структуры и моделирование», Вып. 17, Омск, ОмГУ 2007, с. 53 - 71.
10. Deutsch D., «The fabric of reality: The science of parallel universes and its implications», The Penguin Press, London, 1998, 400 p.
11. Roszkowski L, «Quantum Mechanics», курс лекций на факультете физики и астрономии The University of Sheffield (GB) http://www.shef.ac.uk/physics/teaching/phy202/Topic_15.pdf
12. Elitzur A.C., Vaidman L.. "Quantum mechanical interaction-free measurements", arXiv:hep-th/9305002v2, 5 may 1993, p. 1 – 14.
13. Kwiat P., Weinfurter H., Herzog T., Zeilinger A., Kasevich M. "Interaction-free measurements". Phys. Rev. Lett. **74**, 12 june 1995, p.4763-4766.
14. Vaidman L. The Elitzur-Vaidman Interaction-Free Measurements, 17 Jan 2008, arXiv:0801.2777v1 [quant-ph], P. 1- 8.