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A WAY OUT OF THE WAVE FUNCTION COLLAPSE PUZZLE

EMIL VAPIREV

Department of Nuclear Technology and Nuclear Energy

> "We always have had a great deal of difficulty in understanding the world view the quantum mechanics represents. At least I do, because I'm an old enough man that I haven't got to the point that this stuff is obvious to me. Okay, I still get nervous with it. . . . you know how it always is, every new idea, it takes a generation or two until it becomes obvious that there's no real problem. It has not yet become obvious to me that there's no real problem. I cannot define the real problem, therefore I suspect that there's no real problem, but I am not sure there's no real problem. So that is why I like to investigate things."
>
> R.Feynman, 1982 [1]

Емил Вапирев. ЕДНО ВЪЗМОЖНО ОБЯСНЕНИЕ НА ЗАГАДКАТА, НАРЕЧЕНА "КОЛАПС НА ВЪЛНОВАТА ФУНКЦИЯ"

Предложен е качествен модел на квантовомеханичните резултати, произлизащ от експерименти с единични фотони и двойки корелирани фотони. Моделът на изпреварващи и отразени вълни, който се описва математически в квантовата механика като амплитуди, обяснява и запазва принципа на причинността в експериментите на А.Аспе, експериментите с два интерферометъра, които са по идея на Дж.Д.Франсон, експерименти по Мьосбауеров ефект с брауново движение и експерименти по "изтриване на миналото". В модела на изпреварващи и отразени вълни няма противоречие между свърхсветлинната скорост на изпреварващата вълна и относителност, тъй като частичката, която може да "прочете" интерференчната картина се движи със скоростта на светлината или по-бавно.

Emil Vapirev. A WAY OUT OF THE WAVE FUNCTION COLLAPSE PUZZLE

A qualitative model of quantum mechanical predictions is suggested which is deduced from experiments with single photons and pairs of correlated photons. The advanced and reflected wave understanding, described mathematically in quantum mechanics as amplitudes, is a convenient model which explains and saves causality in the discussed experiments: the A. Aspect's experiments and the experiments with two interferometers following the idea of J. D. Franson, experiments on Mössbauer effect with Brownian motion and the experiments on "erasing the past". In the advanced and reflected wave model there is no contradiction between superluminal velocity of the advanced waves and relativity since the particle which can "read" the interference pattern which is formed eventually faster than light, travels with light velocity or less.

Keywords: entanglement, quantum nonlocality, quantum information

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1. INTRODUCTION

The current and also an old puzzle concerning the wave function is connected with its property to "collapse". The collapse or the reduction of the wave function before the A. Aspect's experiments in 1981–1982 [2] was considered by most of the physicists as mathematical abstraction in certain imaginary (*gedanken*) experiments although real experiments started as earlier, and by very few as something which should be understood literally since it is not a necessary element of the foundations of quantum mechanics. After the theoretical revival by J. Bell [3] of the David Bohm version of the EPR imaginary experiment [4] and the successful experiments with pairs of correlated photons, that mathematical abstraction has caused certain difficulties generally referred to as "non-locality". *Non-locality is just a term which does not explain the phenomenon and is used to name an observation predicted by quantum mechanics that amplitudes which describe distant parts of a quantum s stem at one and the same moment of time can interfere.*

The observation is that pairs of flying in opposite directions correlated photons [2] or pairs of divergent photons obtained by downconversion of light [5], while very far apart are perfectly described by an enormous in dimensions wave function—tens of centimetres, meters, hundreds of meters. But the complication is not associated with the dimensions of the wave function, the complication comes from the observation that both photons behave like a rigid system—the environment which one of the photons meets "influences" the other photon and vice versa. The observations did not change when any possible causality feedback connection along the optical way was terminated by fast switches [2b]. The consequence is "non-locality" and "superluminality", both of which are very hard to comprehend and do not help the understanding. Possibly that comprehension is not just a matter of time till physicists get used to it as R. Feynman says [1]. The experiments of of P. G. Kwiat et al. [6] and P. R. Tapster et al. [7] which followed the idea of J. D. Franson [8] confirmed beyond any doubt the earlier observations of A. Aspect that two distant events can influence each other faster than any light signal could travel between them.

In the last decade of the XX-th century several experimental observations were reported which showed that source and detector form a macro-quantum system and the "future" of a photon can be influenced if something is changed in the "past". The experiments were performed again with pairs of entangled photons (P. G. Kwiat et al. [9], X. Y. Zou et al. [10]) and the interpretation of the authors is that the "future" is erased since by detecting the trajectory of the second photon which is in the "past" we will know "which way" the photons have traversed. The second experiment of X. Y. Zou et al., is even more striking since there are no two photons—one photon is "split" by a semitransparent plate.

Is there a need to "understand" quantum mechanics? The *minimal* viewpoint rejects the necessity since quantum mechanics gives correct answers to problems. Nevertheless a large amount of efforts is aimed at the understanding of quantum mechanics. Those efforts received enormous impact from experiments with two photons with common origin.

A similar view on quantum mechanics is suggested in a recent paper by Klyshko and Lipkin [11]. It is ascertained that when one accepts some well known postulates (Schrodinger, Bohr, Bohm, the statistics of Bose–Einstein and Fermi-Dirac) a model of quantum mechanics is created which makes the interpretation unnecessary. A practical view on the subject is that any interpretation effort is justified if new experiments are suggested. New experiments are also discussed.

The purpose of the present paper is to suggest a qualitative *model* of quantum mechanical predictions deduced from several experiments. "Understanding" is in general a disputable and an undefined process, especially in quantum mechanics, and therefore here we shall confine ourselves within the task of preserving the principle of causality.

2. DISCUSSED EXPERIMENTS

The problems which lead to unresolved contradictions are associated with experiments with two photons with common origin and which have a certain correlation parameter. In fact the problems started with the quantum mechanical description of one photon and the associated "wave-particle duality" but people lived with it until the problems were amplified and developed into hard to understand consequences. The associated De Broglie's wave of a free particle explained most of the experiments.

The textbook double slit experiment is the perfect case for description of the problems in quantum mechanics and therefore we shall start with it. Further developments of the double slit experiment as suggested by J. Wheeler—the delayed choice double slit experiment, just contributed to deepen the contradictions and to make obvious the problems associated with it [12].

In terms of classical waves there are no questions for the observed interference pattern when both slits are open and no interference when one slit is open. What passes through the *other* slit? The usual answer is—the associated De Broglie's wave. The delayed choice double slit experiment realised by C. O. Alley et al. [13] with a Mach–Zehnder interferometer and fast switches further amplifies the question by blocking one of the paths *after* the photon has passed the "double slit" and then no interference occurs. Again, what passes through the other leg of the interferometer which is tens of centimetres away?

The basic problem is that within the present understanding of quantum mechanics we assume that the object which carries energy and its associated wave move in space as one complex entity which we refer to as "the particle". The experiments with the Mach–Zehnder interferometer gives evidence that the wave or an element of it, and the object which carries energy, can be split in space far apart. Obviously the photon has also an associated wave.

2.1. EXPERIMENTS WHICH GIVE EVIDENCE FOR NON-LOCALITY AND EXPERIMENTS IN WHICH "ERASING THE PAST" IS OBSERVED

Here we shall start with the experiments of A. Aspect although experiments with pairs of correlated photons started in 1950 by Wu and Shaknov [14a] with pairs of annihilation 511 keV gamma-rays, later annihilation photons used other authors [14b–g], one group used proton scattering [15].

The source of pairs of photons in the A. Aspect's experiments are atomic cascade transitions excited by lasers—Fig. 1 [1]. The two photons which polarisation is correlated pass through two analysers. The measured quantity is the rate of coincidences as a function of the angle between the analysers. There is a very beautiful elaboration of the experiment with fast rotating mirrors which exclude any possible feedback *with the speed of light* [1b].The light gate (vibrating mirror) is open 10 ns and the necessary time of flight is 40 ns.

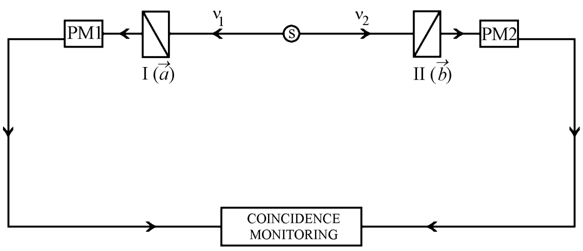

Fig. 1. Principal scheme of the A. Aspect experiment[2]. S – source of correlated photons from atomic cascade excited by lasers, I($\vec{a}$) – crystal which analyses the polarization of a photon fixed at angle $\vec{a}$, , II($\vec{b}$) – crystal which analyses the polarization of a photon fixed at angle $\vec{b}$, PM1,2 – photodetectors the signals from which are connected to the inputs of a coincidence circuit

There are two possible approaches for description of the observations. The first one is by probabilities (local theories) and the second one is by amplitudes. The observation confirms that the phenomenon is described by summation of amplitudes and not by multiplication of probabilities or the system is described by enormous in dimension wave function. The problem, as mentioned in the introduction is not that the wave function is enormous, but with its collapse or when a measurement of the polarisation of one of the photons is performed it affects the result of the measurement of the twin photon.

The most important question is: How or where the mixing of amplitudes occurs? Or how an wave emitted to the left knows what meets the wave emitted *to the right and vice versa if the principle of causality is correct?*

The idea for the experiments of P. G. Kwiat et al. and R. P. Tapster et al. [6,7] was published by J. D. Franson in 1989 [8]. The experimental arrangement is shown in Fig. 2. Highly correlated pairs of photons are produced in a non-linear crystal by parametric downconversion. Initial UV photons are converted into two nearly degenerate photons. A photon pair enters two Mach–Zehnder interferometers and are detected by two detectors. The signals from the two detectors are connected to the inputs of a coincidence circuit.

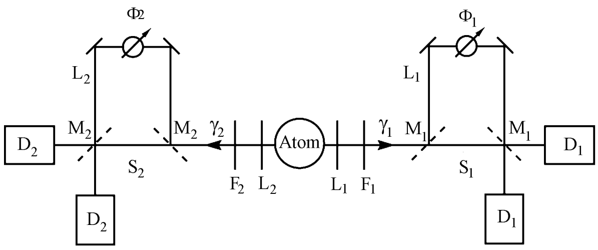

Fig. 2. The scheme illustrating the Franson's idea [8]. Atom – the source of cascade photons, the higher level is long lived, the lower level is short lived with lifetime τ so that (long path)$/c < \tau$, c is the light velocity, L_1, L_2 – lenses, F_1, F_2 – spectral filters, M_1,$M_1^{'}$, M_2, $M_2^{'}$ - semi–transparent mirrors, Φ_1, Φ_2 – phase shift plates, D_1, $D_1^{'}$, D_2, $D_2^{'}$ – detectors

The two Mach–Zehnder interferometers have two semitransparent plates and the photons can traverse the long or the short leg. The presence of the second semitransparent window makes possible interference phenomena. If the path difference is less than the coherent length, then by varying the path (phase) in one of the legs one can detect either 100% of the photons which enter the interferometer of zero photons. If the path difference is greater than the coherence length, then one detects at random 50% of the photons which enter the interferometer.

The idea of the experiment is to check if there are conditions for which there are coincidences—both photons go either both the short legs of the interferometer or the long legs. Of course there are such conditions—if we vary the path lengths in both interferometers. *The idea is, and it is confirmed by the observations, that by varying the path in only one of the legs one can observe coincidences from zero to the maximal possible value.*

The striking results is that in order to observe coincidences both photons have to go either the short or the long way. The experiment shows that for the description of the phenomenon one has to calculate the interference between the short-short way and the long-long way by summation of the corresponding amplitudes. I we assume that there is no frequency difference between the two photons then the total amplitude for coincidences is $A_C = A_{SS} + A_{LL}\mathrm{e}^{i(\Delta\phi_1 - \Delta\phi_2)}$. In case the semitransparent mirrors reflect or transmit 50% of the incident photons, the amplitude is simplified to: $A_C = A_{SS} + A_{LL}\mathrm{e}^{i(\Delta\phi_1 - \Delta\phi_2)} \sim 1 + \mathrm{e}^{i(\Delta\phi_1 - \Delta\phi_2)}$ and the corresponding intensity versus phase difference is $2(1 + \cos^2(\Delta\phi_1 - \Delta\phi_2))$. Here the subscripts SS and LL denote the amplitudes for both photons along the short paths and both photons along the long paths, ϕ_1 and ϕ_2 are the phase differences introduced along the long paths.

The peculiar aspect of this experiment is that in principle we can determine by experiment which way (the short or the long arm) both photons e passed. The photons arrive at pulses at the nonlinear crystal one of the pulses can trigger the start of a time-to-amplitude converter and the stop will be obtained from the coincidence circuit. We shall observe two peaks—one close to the start will correspond to the short arm, the other will correspond to the long arm. Since we can in principle know which way both photons have passed, a real experiment will show the same results with interference. What we do not know is which way both photons will choose.

The result was confirmed by other experimental groups. I want to mention only one of the groups, P. R. Tapster et al., which checked the phenomenon at distance of 4.3 km between the source and the interferometers [7].

The A. Aspect's experiments still left some doubt about the results related to the efficiency of the detectors but the experiments after Franson's idea definitely confirmed that non-locality exists. These and other experiments are discussed in the last paper of B. B. Kadomtsev "Irreversibility in Quantum Mechanics" published after his death [16].

Obviously the description requires summation of amplitudes for events far apart or non-local interference: the source and the two interferometers form a macro-quantum system. The question is "How both photons behave like one object?", or rather "How both photons know in advance their phase difference?", or "How both photons know in advance their paths ?".

There are recent experiments which reveal that the source and all possible states where the particle can be detected form a macro-quantum system in which coherency is lost even if we disturb paths or conditions in the *past.* Such experiments were performed by two groups with pairs of photons obtained by downconversion.

2.2. ERASING THE PAST

In an experiment by P. G. Kwiat et al. [9] highly correlated pairs of photons are produced in a non-linear crystal by parametric downconversion as in the previous experiment. Initial UV photons are converted into two "nearly degenerate" photons which are horizontally polarized. The degenerate pairs are selected by irises and filters. The simplified schemes is shown in Fig. 3. After the reflection from two mirrors the two photons are brought together on a beam splitter which transmits or reflects each photon. Two detectors record the result of the experiment. They detect either coincidences or double energy pulses. If the beam splitter is placed in such a way that the two photons always reach it simultaneously (within their coherence time) interference will occur and the photons will exit only in the direction of one of the detectors and there will be no coincidences. The transmitted and the reflected amplitudes cancel and therefore it is impossible to detect coincidences.

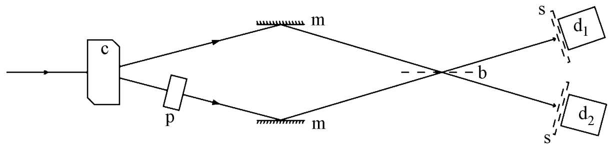

Fig. 3. UV photons are converted into two identical photons by a nonlinear crystal C, After the reflection from two mirrors m the two photons hit a beam splitter b. P – half wave plate, S – polarises, D_1, D_2 – detectors

If a half wave plate at an angle $\varphi/2$ is inserted in one of the arms the polarisation is rotated by φ and coherence is lost. The coincidences and doubles occur at random. For $\varphi/2 = 45^{\circ}$ the loss of coherence is total and the amplitudes are squared before summing. The explanation is that it is possible to tell which photon which way has passed. The information about "which way" can be erased just before the detectors if two polarises oriented at 45° to the horizontal are placed in front of the *two* detectors in such a way as to restore the initial polarisation. The possibility for erasure of the "which way" information is based in the experimental fact that the transmission for 45° and -45° is the same. There are no more coincidences and coherence is restored.

The most important fact about this experiment is that the erasure is performed after the mixing of the amplitudes on the beam splitter. Paul Davies describes the phenomenon in the book "About Time" under the title "Erasing the past" (chapter 7) [17].

"Erasing the past" is very well illustrated in an experiment by Zou et al. [10], although the explanation of the authors is again of the type "which way". Only one UV photon hits a beam splitter (Fig. 4). Along the two paths there

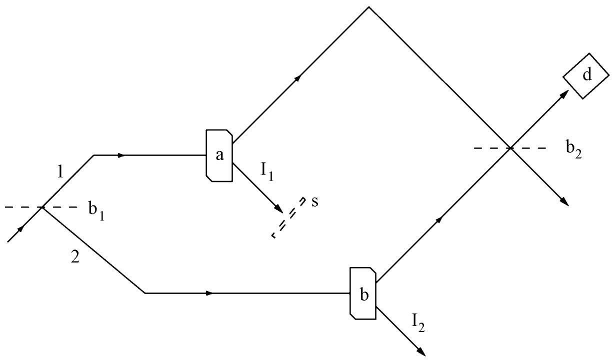

Fig. 4. *Only one* UV photon hits a beam splitter b_1. Along the two paths there are two non-linear crystals (a,b) which can convert the UV photon into two correlated photons. b_2 – beam splitter, I_1 – one of he photons (idler) from crystal a, I_2 – one of he photons (idler) from crystal b, D – detector, there is also a detector in the direction of I_2

are two non-linear crystals which can convert the UV photon into two correlated photons, called "signal" and "idler". The two amplitudes of the "signal" photons are incident on a beam splitter and two detectors, one for the signal photons, the second for the idler photons. The two amplitudes of the "idle" photons are mixed by inserting one "idler" photon amplitude into the lower (on the figure) non-linear crystal. For that arrangement and equal paths of the two signal photons there are no coincidences as in the previous experiment—both photons go into one of the detectors. No coincidences are indicative of a fourth order interference. But there is also a second order interference recorded by the "signal" detector which interference can be observed by scanning the counting rate of the detector by shifting the position of the second beam splitter.

The observation is that if the amplitudes of the two idlers are not mixed, e.g. by blocking the path of the idler from crystal 1, then the second order interference disappears. According to the authors this is *"a rather striking example of a second order interference experiment exhibiting nonclassical features, which is counter-intuitive in terms of both light waves and photons".* The qualitativ explanation is that if the path for idler 1 is blocked, it is possible to tell "which way" the photon has passed. If the detector for the direction I_2 detects a photon then after beam splitter b_1 the photon has passed the lower way (2), if the same detector does not detect a photon, but one of the upper detectors d (shown only one) detects a photon, then definitely the photon has passed the upper path (1).

Again the most important fact about this second experiment is that the erasure is performed after*er*the mixing of the amplitudes on the beam splitter BS_o. The two idler photons are in the past, logically they cannot affect the other two photons with which they have parted.

The conclusion from these two experiments is that the source and all possible detection places where coherence is lost form a macro-quantum system and any disturbance of past conditions affect the final result. The only possible assumptio if we stick to the causality principle is that something amplitudelike traverses the whole system source-detectors-source which results in a constant feedback.

There is group of experiments which show that the source and all detectors form a macro-quantum system which exists for a *certain time* in which summation of amplitudes occurs. These experiments are experiments on Mössbauer effect with Brownian motion.

2.3. EXPERIMENTS ON MÖSSBAUER EFFECT WITH BROWNIAN MOTION

The experiments on recoilless emission and absorption of low energy gamma-rays and Brownian motion are performed with small particles containing micrograms or less of the source or absorber nuclei. The source or absorber particles are immersed in a liquid [18,19].

The experimental set up is shown in Fig. 5 for the case of a solid state source. The Mössbauer source moves with constant acceleration to and from the absorber and scans the energy absorption line. Small solid particles in a liquid which contain Mössbauer nuclei perform Brownian motion. The temperature of the liquid is used for regulation of the process.

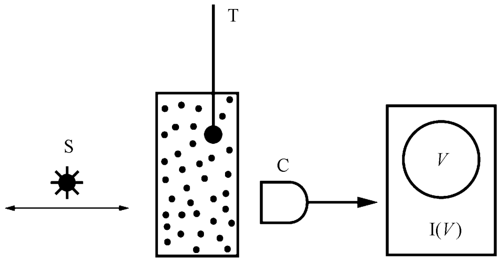

Fig. 5. A scheme for Mössbauer experiment with random motion of the absorber nuclei. The source scans the velocity absorption spectrum. The observed line is a broadened Lorentzian line

The most important result is that the lines of emission or absorption are broadened Lorentzian lines. The random motion does not result in a convolution of a Gaussian and a Lorentzian line. There is a very detailed mathematical description of the phenomenon by Singwi and Sjolander [20]. Here we will follow briefly the description in classical terms by Podgoretskii and Stepanov [21].

The amplitude of the electromagnetic field emitted by a moving damped oscillator is given by

$$a(t) = \exp\left\{i\omega_0 t - \frac{\lambda t}{2} + ikx(t)\right\}, \tag{1}$$

where ω_0 is the resonant frequency, λ is the damping constant, k is the wave number of the emitted radiation, and $x(t)$ is the projection of the oscillator coordinate at time t along the direction of emission. The corresponding frequency amplitude is:

$$b(\omega) = \int\limits_0^\infty \exp\left[-i(\omega - \omega_0)t - \frac{\lambda t}{2} + ikx(t)\right]\mathrm{d}t. \tag{2}$$

If (i) the ratio of the mean free path of the moving particle l and the wavelength L of the incident radiation is $l/L << 1$ and *(ii)* $t_0 << \tau$, t_0 is the average time interval between two interactions, τ is the lifetime of the Mossbauer level, then for random motion the quantity $|x(t) - x(0)|$ has ? Gaussian distribution with dispersion $\sigma(t)$. The major result is that the shape does not depend on the exact path $x(t)$ but only on the square of the mean displacement.

For a diffusion process $\sigma^2(t)$ $=4Dt$, here D *is* the diffusion coefficient. The frequency amplitude for $t = \tau$ is then:

$$b_(\omega) \propto \left[\omega - \omega_0 - \frac{i}{2}(\lambda + 2kD)\right]^{-1}. \tag{3}$$

The point is that the motion is averaged over a time period τ. The observed line is a result of amplitude summation over the lifetime of the excited state. This experiment suggests that we have to include the missing element—the source, the emitting system and to split in time the particle and the associated amplitude wave—the wave before the particle.

3. THE NEW HYPOTHESIS

If we consider the mentioned up to now experiments—the double slit experiment, The experiments with pairs of correlated photons which confirm non-local theories, the experiments on erasing the past, the experiments on Mössbauer effect with Brownian motion, then the process could be as follows:

From the moment of formation of the excited state the excited system and later the emitted particle emit advance waves;

The advance waves traverse the whole system between source and all possible detection places forth and back;

The advance waves form an interference hidden pattern or they make the grid of all possible states that a particle can occupy all around the source.

The idea of reflected waves has a certain indirect confirmation that in the experiments after Franson's idea and the experiments of "erasing the past" all results can be predicted if the sources are the detectors and time is reversed.

What are these advance waves?

In quantum mechanics we calculate amplitudes and the observables are the squared amplitudes. What actually is an amplitude? The major new step here is to assume that amplitudes are emitted as energy free advance (precursor) waves.

A significant problem is the velocity of the advance waves. Several experiments give evidence for superluminal velocities—the A. Aspect experiments with light switches, the G. Weih's et al. experiment [2,22] and the experiments on "erasing the past", specifically that of the P. R. Tapster et al. [7]. *In the advance energy-free waves understanding there is no contradiction between superluminal velocity of the advanced waves and relativity since the particle which can "read" the interference pattern travels with light velocity or less. The velocity of transfer of energy between the source and the detector is restricted since the interference pattern which is formed eventually faster than light can be occupied by a particle travelling with finite velocity between the source and the detector.*

But the velocity of transfer of information between the source and the detector can obviously be greater than the light velocity.

The question "How the advance waves propagate faster than light, what is the mechanism, what is the media?" is another problem and is not the purpose of the present paper.

4. DISCUSSION AND NEW EXPERIMENTS

The advance energy free wave, described mathematically in quantum mechanics as amplitudes and after the act of emission as the de Broglie's wave, is a convenient model which explains and saves causality in the cited experiments. This is a convenient model also for classical light optics—the optimal path and the principle of minimal action. Actually the origin of this idea lies in the origin of quantum mechanics—the wave mechanics.

The process starts with the formation of excited state(s) in the source and ends with an irreversible event—the detection, which terminates coherency. If during the propagation of the particle the conditions are changed incoherently, the wave behaviour is defined only by the De Broglie's wave after the interaction.

In general there is a class of experiments from which we can deduce the velocity of propagation of amplitudes—experiments in which the particle is stripped from its advance waves, or from its history, by a mechanical chopper or by a light switch. Similar experiments have been performed with Mössbauer radiation and fast switches [23] .

A scheme for checking of the possibility for faster than light information transfer can be designed if there is a source which continuously emits particles that are mutually coherent. Then a change in the source emission amplitude influences the interference pattern eventually faster then light and the changed pattern can be "read" by a coherent particle which is far ahead within the coherent length. The far ahead particle has been emitted before the moment of change of the source. The best candidate for such an information transfer is again pairs of photons and setups of the type of "erasing the past". One even can arrange a chain of such modules.

An indirect confirmation of the idea of advanced and reflected waves is that macroscopic quantum systems have been commonly observed. Macroscopic quantum systems have been observed in systems in which a resonance occurs between objects far apart, e.g. a Mössbauer *source-absorber or scatterer nuclei–detector.* The description of the phenomenon of "time filtering" or delay in time in forward direction in Time Delayed Mössbauer Spectroscopy (TDMS) is formally described by one quantum system formed between a nucleus in the source, nuclei in the filter and atoms of the detector [24 a (^{57}Fe), 24 b (^{119m}Sn), not all papers are cited]. A macro–quantum system formed between a nucleus in the source, nuclei in the scatterer and the detector is also formed in the Mössbauer experiments of resonant scattering [25a,b (^{57}Fe), 25c (^{119m}Sn)].

Where is the interference pattern formed? The original Wheeler's experiment gives a hint to this question. If a screen is inserted after the photon passes through the plane of the slits at the place where an interference pattern is formed, then the photon will be detected somewhere on the screen with an appropriate probability for the place. If the screen is not inserted, the photon will be detected along one of the directions defined by the lenses. That interference pattern is formed by waves which have passed both slits, and no screen has been inserted. So the possible empty states are there independently of the presence of the screen. The same holds also for the empty states along the lines of the two initial directions. The conclusion is that there is no need of any substance with which the photons can interact for the formation of empty states. A substance for detection is a cause only for the reflected waves. A very good candidate for the media in which empty states are created by integration of amplitudes is the physical vacuum.

5. CONCLUSION

If the model of the advance waves is accepted this will mean that we accept a universe, which is macroscopically interconnected. For a particular quantum phenomenon, e.g. the emission of a photon, a macroscopic system is formed which consists of the emitting atom, the media surrounding it and all possible positions/states, which can detect the photon. The macroscopic system terminates its existence when the irreversible event of incoherent interaction, the detection, occurs. The present model needs less assumptions than for instance the transactional interpretation of quantum mechanics [26].

What means the term "advanced waves"?

At present there is no idea what the advance waves of a system are and why they carry no energy but carry the properties of the real object except that they are well represented by quantum mechanical amplitudes. Obviously even photons need associated wave and hence advance waves. The same situation is however with the de Broglie's waves which proved to be a very useful assumption for a free particle and a detector. For the time being this model is an indication for a possible way out of the problems arising with causality and path in a quantum system consisting of an emitter which emits one or more particles, the experimental arrangement and free particles and the detector(s) and which model does not contradict known experiments.

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Emil I. Vapirev
St. Kliment Ohridski University of Sofia
Faculty of Physics
Department of Nuclear Technology and Nuclear Energybg

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IN MEMORIAM

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Проф. дфзн Емил Вапирев е роден в гр. Ямбол. През 1972 г. завършва физика, специализация по атомна физика, във Физическия факултет на Софийския университет. През 1974 г. започва работа в Научно-производственото звено на новопостроената АЕЦ "Козлодуй"и участва активно във физическия пуск на нейния Първи блок. През 1975 г. става асистент по ядрена техника в катедра "Атомна физика"на Физическия факултет на СУ. Защитава дисертация в областта на временните зависимости в Мьосбауеровата спектрометрия през 1983 г. През 1998 г. защитава втора дисертация на тема "Елементи на ядрения горивен цикъл: ядрено гориво и нетрадиционни методи за анализ на радиоактивни замърсявания"и получава научната степен "доктор на физическите науки". От 1985 г. до края на живота си работи в новосформираната катедра "Ядрена техника и ядрена енергетика в чието създаване играе основна роля. Доцент, а по-късно професор към тази катедра, той е и неин ръководител в периода 1992-1995 г. Същевременно проф.Вапирев не престава да сътрудничи активно на АЕЦ "Козлодуй"като експерт по ядрения горивен цикъл, а по-късно и като директор на Учебния център при централата. От 2002 г. е Председател на Агенцията за ядрено регулиране на Република България.

Преподавателската дейност на проф. Вапирев е посветена на приложенията на ядрената физика. Той чете курсовете по ядрена безопасност и радиационна защита в АЕЦ, екология на ядрения горивен цикъл, създател е на Лабораторията по ядрена техника във Физическия факултет. Има издадени няколко учебника и ръководства. Научната му дейност е извънредно разнообразна. Автор е на над 60 научни статии и множество доклади на конференции в областта на детектирането на ядрени лъчения, ядрената спектрометрия, приложната ядрена физика.

Неговата огромна научна ерудиция, съчетана с оригинални идеи и заразяващ ентусиазъм привличаха две поколения студенти и дипломанти. Сред физичната общност и колегите си той остава и със своето етично отношение и с несекващото си чувство за хумор, а българската общественост няма да забрави неговата научна компетентност и безкомпромисна борба в защита на българската ядрена енергетика.

Поклон пред паметта му!