Experimental verification of wave function collapse and nonlocality

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Abstract. This article discusses experiments in manipulating the arms of the Mach-Zehnder interferometer, with the corresponding measured change in the interference pattern. The experimental time measurement of periods started with the manipulation of the arms, respectively finalized by the measured change in the observed interference pattern, is considered. The measured time periods and their coordination with the constant speed of light are analysed.

Keywords: quantum optics, wave function collapse, nonlocality, interference

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Abbreviations: QM - quantum mechanics, IP - interference pattern, CI - Copenhagen interpretation, WF - wave function, WFC - wave function collapse, EMW - electromagnetic waves

1. Introduction

The experimental fact of observed interference in light, until the beginning of the last century, is explained by the wave properties of light. But with the development of quantum mechanics (QM) and the proof that light has quantum properties, these newly proven properties must necessarily agree qualitatively and quantitatively with the experimental fact of interference. To explain and reconcile the final result of the interference pattern (IP), the Copenhagen School, creators of the Copenhagen Interpretation (CI), adopts the probability model and the duality of the photon with the properties of both wave and particle. But it follows that the wave function (WF) of each particular photon, of the many photons in the beam, also "satisfies" the instantaneous wave function collapse(WFC), as well as the following (or related, according to some interpretations) effects of quantum nonlocality.

The possibility of proving WF, WFC and the required quantum nonlocality is considered with thought and real experiments which have been written about in many scientific papers. Particular attention should be paid to the review of Klyshko D.N. [1], where in addition to the many literature sources on the issues of QM, some of the problems are considered: measurement of WFC, measurement of partial WFC (also called - partial reduction of the wave function), as well as the exhibition of WFC in the experiments according to the requirements of CI. In conclusion, the author writes: *As far as we know, so far no experimental fact has been found that confirms or refutes the hypothesis of WF* *reduction, and the various models of the measurement process, despite all efforts, remain completely isolated from the experiment.*

The essence of the problems of instantaneous WFC and quantum nonlocality can be most easily clarified with the operation of the Mach-Zehnder interferometer and observed IP. When laser light enters the input of the interferometer, we observe on the screen a standard IP with the corresponding maxima and minima according to the laws of interference. Which, according to CI, is explained by the idea that each specific photon or WF of the photon, in an unknown way "knows" the whole experimental setup and "determines" the hit (redistribution, reduction) of the photons to form a standard IP. But this does not agree with the proven properties and the fact that the photon is indivisible, and passes only on one arm of the interferometer, as well as the fact that WF is only a mathematical idea, and has no physical reality. Therefore, it cannot "know" and "determine" the redistribution of photons to form IP.

However, when manipulating the interferometer, for example, we change the optical path in one arm with a distance λ/2, see [2], and the considered techniques for changing the optical path with λ/2. Then each manipulation of the arm with a distance - λ/2, leads to an exchange of the location of the maximum and minimum of the IP, i.e. leads to a change in the IP. But the two processes, manipulation of the arm, and change of IP must be simultaneous, a consequence of the instantaneous WFC, required by CI. But such simultaneity of the two independent processes is in clear contradiction with the experimentally proven properties of the constant speed of light in the arms of the interferometer, see [1], and the considered partial reduction of WF. As in this case, to check the instantaneous WFC, since WF has no physical reality, respectively is unobservable and immeasurable in principle, even according to CI, we can only measure the final result of the changed IP as a result of the manipulation.

As in this case, we have two real independent processes, manipulation in the arm of the interferometer and a corresponding change in the IP, which according to CI and instantaneous WFC, must be simultaneous, which simultaneity can already be tested experimentally. In this article, which we accept as a continuation of [2], we will consider experiments in which to experimentally measure, analyse, and verify the simultaneity of the two considered processes, taking into account the regularities of interference, and constant speed of EMWs in the interferometer arms.

2. Experimental verification of collapse of the wave function, and nonlocality with the Mach-Zehnder interferometer

2.1. Theoretical principles

The essence of the experiments examining the verification of instantaneous WFC, and possible nonlocal effects, and processes, we can verify with the following logic. We have a working Mach-Zehnder interferometer, and an IP observed on the screen with the corresponding interference fringes, i.e. maxima and minima according to the laws of interference. Assume that the arms of the interferometer have a size of 100 m, as discussed below, see Fig.1. (a). If we manipulate one arm of the interferometer, for example, extend the optical path by λ/2, then the maximum and minimum of the IP will swap places, i.e. we have a change in IP that we can actually measure. Thus, we have the two real independent processes, manipulation, and change of IP, which we can measure, and accordingly check the simultaneity of the two processes, required according to the instantaneous WFC, which is mainly of interest to us. Note that in order to have a correct result regarding simultaneity, the two processes must be as short as possible, and each must be accurately measured (fixed) in time.

The manipulation process can be performed with a Pockels cell, implemented as an integrated optical device, see [4] 20 chapter, which has a trigger time operation of less than 10^{-11} s. When an appropriate voltage is applied to a Pockels cell, which corresponds to a change in the refractive index (Δn) [4], analogous to the extension of the optical path by λ/2, as discussed in [2]. After the trigger time, at the output of the Pockels cell, we have phase retardation with λ/2 for the current passing EMWs. The beginning of the triggering process, which begins with the inclusion of the voltage on the Pockels cell, is accordingly the beginning of the manipulation process, which for convenience below, we will consider and call the ‘start’ of the manipulation process.

The process of exchanging the location of the maximum, and the minimum, considered as a change of IP, a consequence of the phase retardation in the manipulated arm, which will occur after the EMW with phase retardation reaches the screen, can be measured as follows. The interference pattern observed on the screen E, for the horizontal output of the interferometer, see Fig.1. (a), as graphically shown, we can do with two photodiodes D1 and D2. As a photodiode, D1 is positioned to "see" only one of the IP maxima (fringes), and D2 is positioned to see only one of the IP minima. Such an experimental technique for independently observing the maximum and minimum of IP by appropriate positioning is known in experimental optics, see [3]. Thus available to D1 and D2, the light intensity that falls on them will change when the IP changes (due to phase retardation), respectively, we can measure the moment of this change in intensity, which we will call conditionally the ‘final’ of the process of changing the IP.

So we have a real measurable time interval from start to final, which we are mainly interested in, which for convenience we will call τ_{sf}. Note that the duration of τ_{sf}, in addition to the trigger times of the Pockels cell and photodiodes, will depend on the distance - L, which EMW will travel to the screen after acquiring the phase retardation at the output of the Pockels cell, by law $t = L/c$, where c is the speed of light.

2.2. Experimental verification

The First variant of the experiment. To the input of a symmetrical Mach-Zehnder interferometer Fig.1. (a), a laser beam from a laser L is directed. The translucent mirror P1 divides the laser beam into two beams of equal intensity in both arms of the interferometer. In each of the arms, next to the translucent mirror P1, are placed Pockels cells PC1, and PC2, made as integrated optical devices. Mirrors M1, and M2 are reflective, and P2 is a translucent mirror that divides the intensity to the two outputs of the interferometer, on which we observe IP on screen E, as shown in the drawing. The monitoring of the IP at the horizontal output is replaced by two photodiodes D1, and D2, as the photodiode D1 is positioned to "see" only one of the maxima (fringes) of the IP, while D2 is positioned to “see” only one of the minima of the IP, as shown in Fig.1. (a). Thus available to D1, and D2, the light intensity that falls on them will change the voltage (resistance), and the outputs of D1, and D2, which voltages are submitted to a fast comparator – K (considered as fast electronic circuit for matches), as indicated in the drawing. Respectively at the output of the comparator t_f, we will have zero voltage for the located and "illuminated" D1, and D2, and selected mode of K, which for convenience we will consider as the basic state of the IP, and the output t_f, and the phase difference between the two interfering beams we assume to be zero.

But when we include an appropriate voltage at point V connected to PC1, as shown in Fig.1. (a), which we consider as the start of the manipulation process, measured at point t_0. After the trigger time of PC1, the successive EMWs at the output of PC1 with phase retardation λ/2, after the time for which the EMW will reach the photodiodes, according to the law L/c, the phase difference between the two interfering beams will change according to the phase retardation λ/2. Then the maximum and minimum of the IP will swap places, and in this case, photodiode D1 will see a minimum, and photodiode D2 will see a maximum of IP. Accordingly, the output of the comparator t_f will change its state, from the current zero voltage to the maximum operating voltage, which we consider as the final of the process of changing the IP. As in this case we already have, the start of the manipulation process, which we measure at point t_0, as well as the final of the process change of IP, which we measure at point t_f, which non-simultaneous processes start, and final can be measured with a two-beam oscilloscope.

In Fig.1. (b) (left part of the drawing), the timing diagram of the measured processes start, and final is shown, as the size of the interferometer, the distance from P1 to D1, and D2 are taken as equal to 100 m. At the input of the oscilloscope t_0, we measure the voltage at point t_0, corresponding to the start of the manipulation process, and at the input t_f, we measure the voltage at point t_f, corresponding to the final of the process of changing the IP. Accordingly, the duration of time τ_{sf}, which we are mainly interested in, can be measured and analysed.

Note that the time τ_{sf} is obtained by two factors. The first factor is the trigger times of the Pockels cell, the photodiodes and the comparator, which will be referred to as t_S. The Pockels cell, designed as an integrated optical device, as well as the photodiodes, can operate at a frequency greater than 100 GHz, see [4] 20 and 18 chapters, i.e. trigger period $T = 1/\nu$, and have a value $\leq 10^{-11}$s. Electronic circuits, such as comparators, also operate at frequencies above 100 GHz, i.e. trigger time also $\leq 10^{-11}$s. The timing diagram Fig.1. (b) the trigger times are shown: t_1 is the trigger time of PC1, t_2 is the trigger time of D1, and D2 and t_3 is the trigger time of the comparator K. As the sum of the trigger times for the three elements, $t_S = t_1 + t_2 + t_3$, for convenience we will round to 10^{-10}s.

The second factor determining the time τ_{sf}, is the time for which, EMW acquired phase retardation in PC1 will reach the photodiodes according to the law L/c, where L is the distance from PC1 to the photodiodes, and c is the speed of light indicated on the timing diagram Fig.1. (b) as t_C. In this case, since PC1 made as an integrated optical device has a minimum size compared to the interferometer, we conveniently ignore the size of PC1 so that we consider the size of the interferometer from P1 to the photodiodes. Accordingly, the time t_C, for a size of 100 m on the interferometer is $L / c = 3{,}333.10^{-7}$ s, so the time $\tau_{sf} = t_S + t_C = 3{,}334.10^{-7}$s, and as a chronology has the following sequence $\tau_{sf} = t_1 + t_C + t_2 + t_3$. Note that since $t_C >> t_S$, the scale of the considered times of the drawing is not observed.

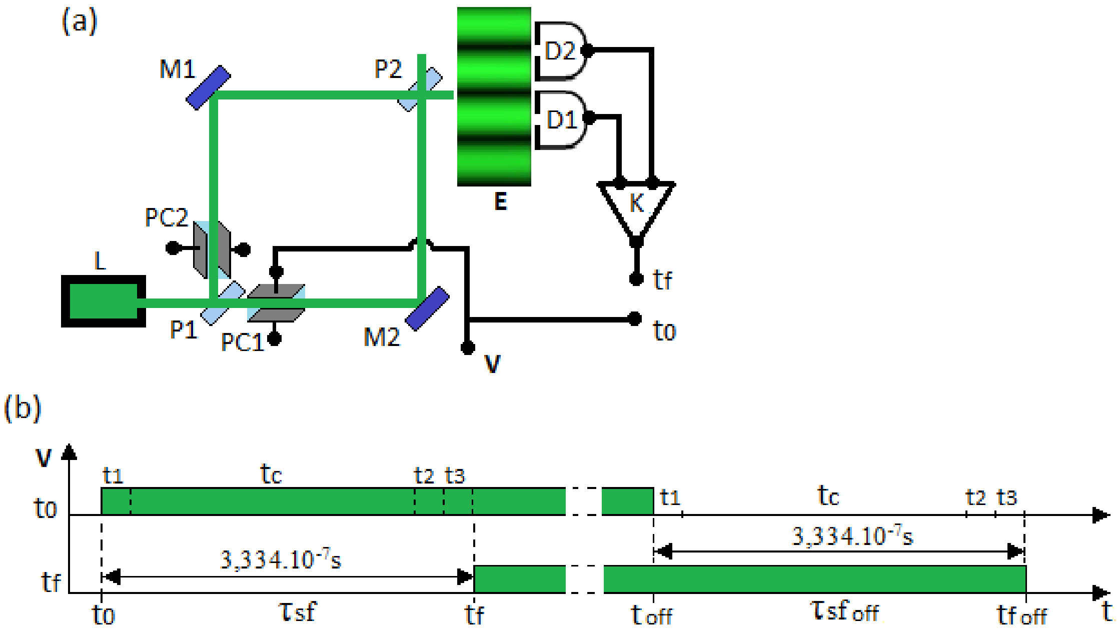

Fig. 1. (a) A symmetrical Mach-Zehnder interferometer, PC1 and PC2 are located next to P1. When switching voltage on, or off to PC1 at point V, the displacement of the maximum of the IP is measured at the output t_f, as graphically shown in the drawing. (b) Timing diagram when the voltage is switched on (left part of the drawing), starts from time t_0 and ends with t_f, the measured time $\tau_{sf} = t_1 + t_c + t_2 + t_3 = 3{,}334.10^{-7}$ s. Timing diagram when the voltage is switched off (right part of the drawing), starts from the time t_{off} and ends with t_{foff}, the measured time $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$ s.

Note that the wire lengths from point V to PC1, and t_0 are equal, as are the wires from the outputs of D1, and D2 to the comparator, i.e. it is obligatory to observe the symmetry of the signal path for the whole setup Fig.1. (a). Note that the time t_S is irremediable in the experiments, but has a well-defined value set by the elements used, and can be measured, in addition, the time $t_C >> t_S$, so that t_S is not directly related to the main conclusions.

Note that with the inclusion of the voltage at point V, it remains permanently switched on indefinitely, respectively the time τ_{sf} can be measured once, as shown in the timing diagram Fig.1. (b) (left side of the drawing). Note that the exclusion of voltage, which is discussed below, for convenience we will denote as t_{off}, i.e. the times considered when the voltage is switched off are marked - off (right part of the drawing) in order to be different from the other time intervals and processes.

Thus, switching off the voltage at point V will return the IP and the output of K to the basic state thus considered before switching on the voltage. Because, after the moment of switching off the voltage t_{off}, considered as the start of the manipulation process, after the trigger time t_1, at the output of PC1, the phase retardation for the current passing EMWs will be terminated. Accordingly, after the time t_C, the EMW with terminated phase retardation will reach the photodiodes, where the phase difference between the two interfering beams will be zero again. Which will return the IP to the basic state thus considered, and after the time t_2, and t_3 it will return to the basic state the output of K, measured at the input of the oscilloscope t_f, and shown as the time t_{foff}. Then the measured time period τ_{sfoff}, will have the same sequence and value as τ_{sf}, i.e. $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$s, and we can also observe once.

The Second variant of the experiment. We consider the same experimental setup, the only difference being that PC1 is located next to P2, Fig.2. (a). As in this case, we have positioned D1 to see only one of the maxima, and D2 to see only one of the IP minima, respectively at the output of the comparator we have zero voltage, which we consider as the basic state of IP, and output t_f.

But when we turn on the voltage at point V, measured at the input t_0 (considered as the start of the manipulation process), then after the trigger times $t_S = t_1 + t_C' + t_2 + t_3$, at the input t_f (considered as the final of the IP process change) we will now measure the maximum operating voltage, as shown in the timing diagram Fig.2. (b) (left part of the drawing).

Note that the time t_C', for which the light will travel the distance from PC1 to the photodiodes, which distance considered theoretically, has a minimum size of about 10 mm, then t_C' has a value $\approx 3{,}3.10^{-11}$ s. Since the time $t_C' << t_C$ (t_C from the first variant), therefore the time t_C' has no direct relation to the final conclusions, and for convenience in this case we have included it to the average response time $t_S = 10.10^{-10}$ s. As in this variant, the time $\tau_{sf} = t_S = 10^{-10}$s, i.e. we will only measure the trigger times t_s (ignoring the consideration of t_C' for convenience).

The same sequence, and logic for the time period τ_{sfoff}, we will get when we turn off the voltage at point V, so shown time periods t_{off} on diagram Fig.2. (b) (right part of the drawing). As the time point t_{off} considered, as the start of the process manipulation after the trigger time t_S, will lead to zero output voltage t_f, measured as the time τ_{foff}, considered as the final process change on the IP, i.e. we have a return to the so-called basic state of the IP, and the output t_f. Accordingly, the time τ_{sfoff} will have the same sequence, and value as the time τ_{sf}, i.e. $\tau_{sfoff} = t_1 + t_C' + t_2 + t_3 = t_S = 10^{-10}$s, which we can measure once (as in this case, we have included the time tc' to the trigger time t_S).

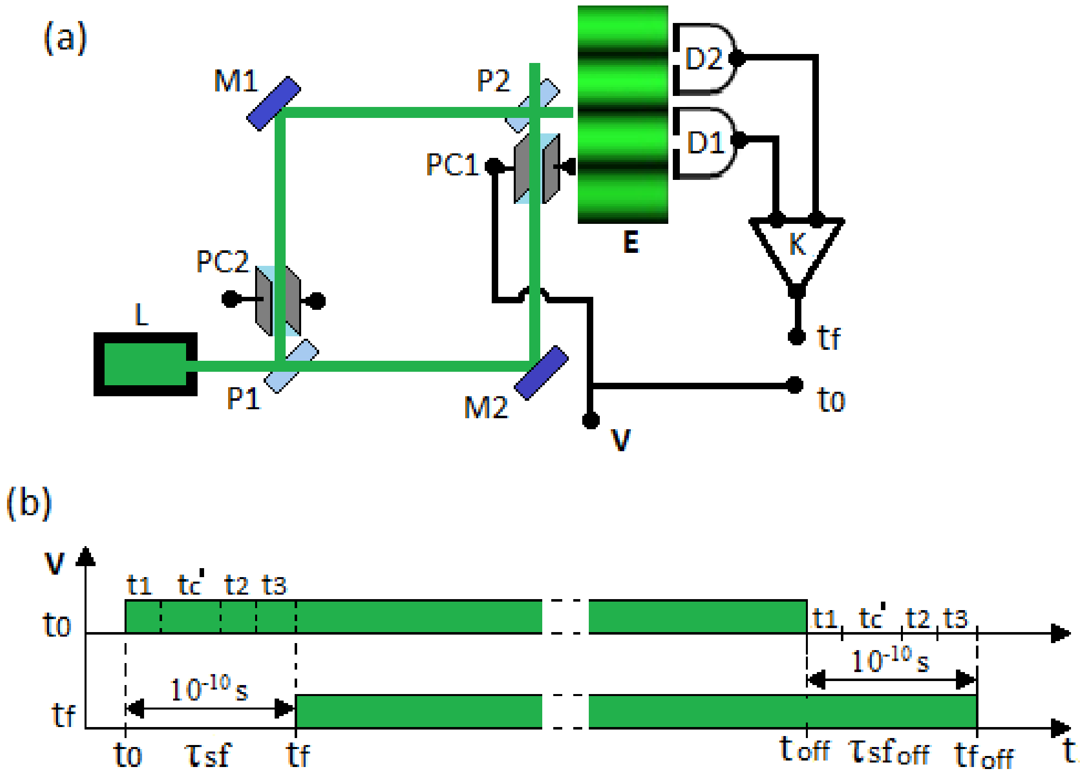

Fig. 2. (a) A Mach-Zehnder symmetric interferometer, PC1 is adjacent to P2, and PC2 is adjacent to P1. When switching voltage on, or off to PC1 at point V, the displacement of the IP maximum is measured at the output t_f. (b) Timing diagram when the voltage is switched on (left part of the drawing), starts from time t_0 and ends with t_f, the measured time $\tau_{sf} = t_1 + t_C' + t_2 + t_3 = 10.10^{-10}$ s. Timing diagram when the voltage is switched off (right part of the drawing), starts from time t_{off} and ends with t_{foff} , time $\tau_{sfoff} = t_1 + t_C' + t_2 + t_3 = 10.10^{-10}$ s.

The Third variant of the experiment. We consider the same experimental setup following the same logic, and conditions, as the only difference between the second and third variant is that the wire from point V is connected not only to PC1 but also to PC2 Fig.3. (a). As in this variant, before switching the voltage to point V, we have the so-called basic state of the IP, and the output t_f.

But when we turn on the voltage at point V, measured at the input of the oscilloscope t_0 shown as the time t_0 of the timing diagram in Fig.3. (b), considered as the start of the manipulation process. After the trigger time $t_S = t_1 + t_C' + t_2' + t_3'$, at the output t_f we will measure the maximum operating voltage, which is the trigger time due to the phase retardation of PC1, denoted as t_f-PC1, considered as the final process change of IP, but as a result of EMW passed after PC1. As in this case, the trigger time $t_S = t_1 + t_C' + t_2' + t_3' = 10^{-10}$s has the same value, and sequence as in the second variant already considered. Respectively, when D1 and D2 reach the EMW for the time t_C (passed on the arm P1, M1, and P2, according to the law L/c), with phase retardation due to PC2, then after the time of trigger t_2 and t_3, the output of the comparator t_f, which has a current maximum operating voltage will change its state to zero voltage, indicated in the drawing as the time t_f-PC2.

Note that the time τ_{sf}, which starts from t_0, and ends with t_f-PC2, is identical in value and sequence to the time considered in the first variant, $\tau_{sf} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$s, but does not include the times t_c', t_2' and t_3', because time t_C starts after t_1 (times t_C', t_2', t_3' and time t_C run in parallel as a chronology). As in this case, despite the fact that the voltage is connected simultaneously to PC1 and PC2, the times t_f-PC1, and t_f-PC2 are not simultaneous at the output t_f, respectively at the input of the oscilloscope t_f

we measure a time pulse, as shown in Fig.3. (b). As the pulse duration starts after t_f-PC1(t_3') and ends after t_f-PC2 (t_3), respectively there is a value τ_{sf} - $t_S \approx 3{,}333.10^{-7}$ s, where $t_S = t_1 + t_C' + t_2' + t_3' = 10^{-10}$s.

But when we turn off the voltage at point V, no matter after how long time, as shown in the timing diagram Fig.3. (b) (right part of the drawing). Measured at the input of the oscilloscope t_0, and shown as the time t_{off}, considered as the start of the manipulation process. The ongoing zero voltage we have at t_f, after the trigger time t_1, t_C', t_2' and t_3', due to the terminated phase retardation by PC1, at the input of the oscilloscope t_f, we will measure the maximum operating voltage, denoted as the time t_f-PC1off. Respectively, when D1 and D2 reach the EMW with the terminated phase retardation due to PC2 for the time t_C, then after the trigger time t_2, and t_3, the output t_f, which has a current maximum operating voltage, will change its state to zero voltage, indicated in the drawing as the time t_f-PC2off, considered as the final of the IP change process. As in this case, we obtain and measure the time τ_{sfoff}, and time pulse, analogous to the consideration when the voltage is turned on. Accordingly, the time $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$s, does not include the times t_C', t_2' and t_3' because the time t_C starts after t_1. Just as the pulse duration starts after t_f-PC1$_{off}$ (t_3') and ends after t_f-PC2$_{off}$ (t_3), it has a value of τ_{sfoff} - $t_S \approx 3{,}333.10^{-7}$ s, where $t_S = t_1 + t_C' + t_2' + t_3' = 10^{-10}$s. As in the case, when switching off the voltage, the time τ_{sfoff} and the pulse can be measured once.

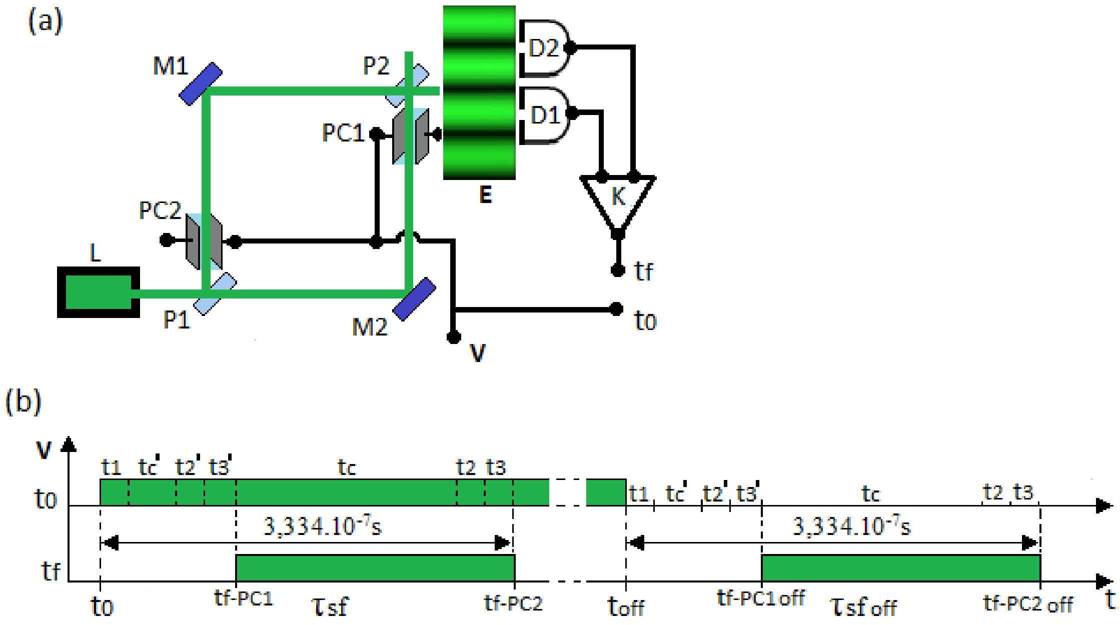

Fig. 3. (a) Symmetrical Mach-Zehnder interferometer, PC1 is adjacent to P2, and PC2 is adjacent to P1. When voltage is switched on or off to PC1, and PC2 at point V, the displacement of the IP maximum is measured at the output t_f. (b) Timing diagram when voltage is switched on (left part of the drawing), the measured time τ_{sf} starts from time t_0, and ends with t_f-PC2, and has value $\tau_{sf} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$ s (time t_C starts after t_1, so that the times t_C', t_2', t_3' do not participate in the time interval τ_{sf}). Timing diagram when the voltage is switched off (right part of the drawing), the measured time τ_{sfoff} starts from the time t_{off} and ends with t_f-PC2$_{off}$, and has the value $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$ s. The time of the pulses thus obtained, when the voltage is switched on (switched off), started by t_f-PC1(t_f-PC1$_{off}$), and finalized by t_f-PC2(t_f-PC2$_{off}$), is equal to τ_{sf} (τ_{sfoff}) – $t_S \approx 3{,}333.10^{-7}$s, $t_S = t_1 + t_C' + t_2' + t_3' = 10^{-10}$ s.

In the considered processes from start to final, it is obligatory to take into account the phase difference between the two interfering beams when they reach the screen (photodiodes). Before switching on the voltage, we have a zero phase difference between the two interfering beams $f_1 = f_2$ (f_1 - the beam after PC1, and f_2 - the beam after PC2), the IP has the so-called basic state, and the output t_f has zero voltage. When we turn on the voltage, due to the phase retardation of PC1 with $\lambda/2$, after time t_C', we already have a phase difference between the beams $f_1 \neq f_2$, respectively IP is changed, and after time t_2', and t_3', the output of t_f already has a maximum operating voltage. But the inclusion of voltage is a simultaneous process for PC1, and PC2, respectively due to the phase retardation of PC2, after the time t_C, EMW passed on the arm P1, M1, and P2 are also with changed phase, then already, the phase difference between the two interfering beams no $f_1 = f_2$, the IP has the basic state thus considered, and after the time t_2, and t_3, the output t_f has zero voltage. The same logic of change between the phases of the two beams is obtained when we turn off the voltage at point V, Fig.3. (b) (right part of the drawing). Accordingly, in this case, as well, the phase retardation due to the switched-off voltage is terminated simultaneously for PC1, and PC2, but the EMW with terminated phase retardation reaches the photodiodes at different times.

3. Summary

The considered experiments, and the obtained results, see table - 1, prove that there are no effects due to instantaneous WFC, and nonlocality. The requirement according to CI, each photon, regardless of which of the arms of the interferometer passes, to "react" instantly when we manipulate one of the arms, with the corresponding instantaneous change of IP, is not observed (measured). Like all the results in Table 1, they can be explained qualitatively and quantitatively only by the determinism, and the constant speed of light in the arms of the interferometer, without the need for instantaneous WFC, and nonlocality.

Table - 1. Results of the experiments from point 2

№	Time chart	Location of PC1, and PC2, relative to P1 and P2	Include and switching off V to PC1, PC2	Time of τ_{sf}	Time of τ_{sfoff}	Effects of instant WFC
1	Fig.1. (b)*	PC2 – P1 – PC1	PC1	$3{,}334.10^{-7}$ s	$3{,}334.10^{-7}$ s	-
2	Fig.2. (b)**	PC2 – P1, PC1 – P2	PC1	10^{-10} s	10^{-10} s	-
3	Fig.3. (b)***	PC2 – P1, PC1 – P2	PC1, PC2	$3{,}334.10^{-7}$ s	$3{,}334.10^{-7}$ s	-

* The times; τ_{sf}, $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$ s. Time $t_C = 3{,}333.10^{-7}$ s.

** The times; τ_{sf}, $\tau_{sfoff} = ts = t_1 + t_C' + t_2' + t_3' = 10^{-10}$s. Time $t_C' \approx 3{,}3.10^{-11}$s.

*** The times; τ_{sf}, $\tau_{sfoff} = t_1 + t_C + t_2 + t_3 = 3{,}334.10^{-7}$ s. The time $t_C = 3{,}333.10^{-7}$ s and starts after t1. The pulse time when switching on (off) the voltage started by t_f-PC1 (t_f-PC1$_{off}$), and finalized by t_f-PC2 (t_f-PC2$_{off}$) has a value τ_{sf} (τ_{sfoff}) - t_S, where $t_S = t_1 + t_C' + t_2' + t_3' = 10^{-10}$s.

The only case when we can assume the effects of instantaneous WFC is in the second variant, and timing diagram Fig.2. (b), but only if we consider the case in isolation from the other variants. Where it can be assumed that when we manipulate PC1, after the trigger time t_1 (time t_1, as well as times t_C', t_2, and t_3 are irremovable in the experimental setup), then all photons in both arms somehow "understood" this, and accordingly we have a shift of the maximum, considered as the final of the process of changing the IP. But such a conclusion cannot be reconciled with the results of the first, and third variants. In addition, there is a normal deterministic explanation for the result of the second variant, because when PC1 activated, the successive EMWs (photons) with phase retardation reach D1, and D2, without the need for time, i.e. the distance L, as well as the regularities of L/c do not participate (in the case of convenience in this theoretical consideration we ignore the time t_C').

It should be noted that in the considered third variant, for the time after switching off the voltage, it is most clearly seen that there were no effects of instantaneous WFC, and nonlocality and we do not have to consider them. Because, after switching off the voltage, which is both for PC1 and PC2, this manipulation on the interferometer is the last, respectively all considered times, and pulse duration, follow chronologically and strictly deterministic, with mandatory consideration of the constant speed of light in the arms of the interferometer under the law L/c. Accordingly, one sees the whole insolvency of the CI, and the claim that the photon interferes alone as if it were in both arms of the interferometer at the same time, a naive notion sometimes considered, or in an unknown way "knows" the whole experimental setup to react, and it instantly, with a change in the IP. As in this case, it was proved that the instantaneous WFC, and the effects of nonlocality have no real relation to the obtained experimental results, but are only a mathematical idea imposed for internal coordination of CI. Furthermore, there is a maximum displacement only when the manipulated phase retardation of the EMW from one beam has reached the location where the two beams intersect before being projected onto the screen, i.e. the effect of the influence between the EMW (photons) of the two beams, considered mainly in [2], is also indirectly proved.

The experiments considered in Table - 1 can be performed in any laboratory of optics, without the need for complex or expensive equipment, in fact, the results can be derived theoretically, using experimentally proven laws of constant speed of light. The obtained pulse in the third variant can be used as a time reference because its duration is a function of the different distances of PC1 and PC2 to P2, as well as for obtaining the shortest pulses in electronics and microprocessors when it is implemented as an integral-optical device.

The experiments in Table 1 are based on standard proven regularities, but in this case, the measured times and processes, as well as the dynamics of the different time processes that run in parallel in time, complicate to some extent the perception of the entire newly introduced consideration of processes is presented computer animation, which should be considered only as supporting material - https://www.youtube.com/channel/UCKRHTPajIyqMPUCWp_Ps-xA

Missing effects of instantaneous WFC and nonlocality can also be proved if we partially modify the experimental formulation of Fig.1. (a). As PC1 instead of next to P1, we place next to the mirror M2, in this case, it does not matter before or after M2. In order not to violate the equality of intensity and the observed IP, in each side of the thus formed square of the interferometer, we place an additional translucent mirror. Place P3 between the mirrors M2, and P2, place P4 between M2, and P1, place P5 between M1, and P1, and place P6 between M1, and P2. In this way, a reflected laser beam from one of the additionally placed translucent mirrors (P3, P4, P5, and P6) can be directed to a beam reflected from another translucent mirror so as to form an additional interferometer, and to observe the IP. As a shift of the maximum, when we turn on or off the voltage of PC1, there will be only if one of the pair of interfering beams is from a translucent mirror P3 (located after PC1), respectively there will be no displacement of the maximum if the pair of interfering beams do not reflect by P3, i.e. the manipulation on PC1, and the corresponding phase retardation change the phase only of the EMW propagating after PC1, while the EMW (photons) propagating to the other parts of the interferometer are in "ignorance" of the manipulation on the PC1.

4. Conclusion

The notion accepted by CI that the photon (light) has wave-corpuscular properties has not been proven so far with definite experiments, but nevertheless, in most scientific papers, the duality of the photon is accepted and considered as a given, the basis on which further notions and principles are built. According to this view, at the input of the interferometer, after the first translucent mirror, the photon is viewed with dualistic properties so as to be consistent with the observed fact of interference. With the introduced uncertainty that we do not know which of the arms a particular photon passes through, as this uncertainty of the photon "manages" the received IP, are only mathematically required rules, true in principle, but imposed only for internal coordination of CI. The problem is that these properties require the photon, even though it is indivisible, to "know" the whole experimental setup and when we manipulate one of the arms of the interferometer, to "react" (change the IP) instantly.

In fact, all the processes and times discussed in this article are not considered consistently, and comprehensively in the so-called delayed-choice, quantum eraser and quantum correlation experiments, with which CI aims to prove the real "influence" of WF on the experimental IP result. As the times t_0, t_f, t_S, t_C, τ_{sf} and received pulses considered in this article, not all of them are analysed correctly when possible, and they cannot be analysed and measured in principle due to the specifics of the experimental setups used in the experiments with delayed-choice experiment, quantum eraser and quantum correlation. However, in some cases, "fundamental" conclusions are drawn, leading to teleportation of the state of a quantum object, and speeds exceeding the speed of light. One of the problems of experiments proving CI is that instead of manipulation for a quantum process, modulation is used, regardless of its type. But modulation is usually a fast periodic process, repeated over time, so that each period (frequency, repeatability of modulation) is indistinguishable from another modulation period when two or more modulated periods are located in the arms of the interferometer, i.e. in experiments using modulation, analysis and measurement for all times from start to final is impossible. However, the advantage of the manipulation process used is that all times from start to final can be measured and analysed, as they are one-time, both when switching on and off the voltage at point V.

With the experiments considered in Table **-** 1, the effects of instantaneous processes and nonlocality are not observed (measured), on the contrary, the results are deterministic, and follow the chronologically constant speed of light in the arms of the interferometer. Like all results, according to Table **-** 1, can be explained qualitatively, and quantitatively only with determinism, and constant speed of light, without the requirement for instantaneous processes and nonlocality. In addition, there is a maximum shift only when the manipulated EMW phase difference from one beam has reached the screen (photodiodes), i.e. the effect of the process of influence between the two beams (EMW, photons), considered as the model of influence in [2], is also indirectly proved.

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