On the nature of the waves of Einstein de Broglie

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ABSTRACT. A new method for empty wave detection, based on incoherent wave mixing, with random emitting sources is presented.

RESUME. Nous présentons une nouvelle méthode pour détecter des ondes vides avec des sources émettant au hasard. Cette méthode est basée sur les mélanges d'ondes incohérentes.

1. Introduction

The interpretation of the quantum formalism has not been an easy matter. From the very begining great polemics have been fought [1]. For one side the quantum formalism can be seen as a powerfull mathematical device very usefull to predict the outcome of the possible experiments, but having no concern with any hypothetical deep reality. On the other side it can be interpreted as a reasonable representation of a more profound physical reality which could be improved with the development of the human knowledge. The first position is the one known as the usual interpretation of the quantum formalism also called the Copenhagen interpretatiom of quantum mechanics. Till today this interpretation as been able to predict every experimental result, in the quantum domain, with the highest precision. This is a very good reason why it as been accepted by the great majority of the scientific comunity. Nevertheless some of its conclusions, namely the negation of the **objective reality** and the impossibility of going beyond the formalism, are not easily accepted. This lead to a refutation of this current, in such a way that the disagreement with the fundations of quantum mechanics grew and is now greater than ever. Those facts gave rise to alternative causal interpretations. One of those theories *the causal theory of de Broglie* , perhaps the most developed of them all, is able to to predict and explain, in a natural way, in the framework of spacetime, most of quantum phenomena.

For long time the existence or non existence of a physical reality beyond the quantum formalism could not be solved! As long as no experimental evidence could confirm the validity of the causal theory of de Broglie its acceptation shall remain a matter of faith. Only recently [2] it was possible to clear and develop the basic concepts conducing to proposals of concrete experiments which could, in principle, decide about the validity of the usual or the causal theory.

One possible way out is based on the different meanings given to the wave function ψ, solution of the evolution equation. According to the Copenhagen interpretation [3] the function ψ_u (where u stands for the usual interpretation) is no more than a probability wave, normalized at will, carrying all available information about the microsystem. Thus the function ψ_u is only a predictive mathematical tool having nothing to do with any hypothetical deep reality. The double solution theory of de Broglie [4], on the contrary, claims that the function ψ_c (c for causal) represents a real physical wave propagating in space and time according to a certain evolution equation. The physical wave ψ_u, with almost no energy carries and guides the singularity (corpuscle). A particle, in this theory, is seen both as a wave and as a corpuscle. Practically all the energy of the particle is transported by the singularity.

2. Empty Wave Generator

Let us consider a source of microparticles, neutrons for instance, emiting one by one, in such a way that in the experimental apparatus no more than one particle can be found at a time, Fig.1.

The quantum system described by the wave function ψ is splitted into two wave trains at Bs, each one following a well defined separated trajectory. If the reduction detector D_R placed in the path of wave train ψ_2 reacts and switches on the light which is seen by the observer Obs. what can be concluded about the wave train ψ_1 ?

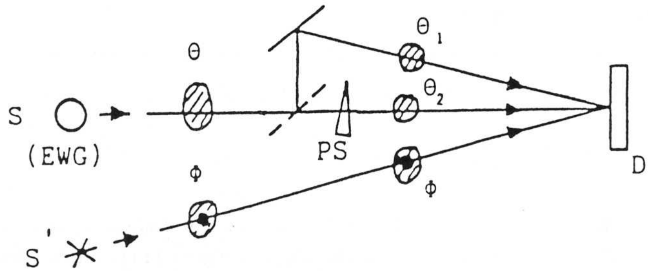

Figure 1. The source S emits a quantum system (neutron) one at a time. After striking the beamsplitter Bs the wave train ψ is divided into two. If the reduction detector D_R is triggered the observer sees the light.

The answer to this question depends on the theory:

According to the Copenhagen interpretation of the quantum formalism, the wave function ψ is nothing more than a mathematical probability without objective nature. In this case, if the neutron is detected along the path of ψ_2 the probability of being found at the other is zero, so one must conclude that $\psi_1 = 0$. This is the famous phenomenon known as the reduction or collapse of the wave function by measurement. Summing-up after detection and observation the probability wave having accomplished its role of information carrier desappears.

The answer given to the question by the theory of de Broglie is entirely different. In this interpretation the source S emits one neutron, that is a wave plus a singularity. The real wave $\psi_c \equiv \phi$ at the beamsplitter Bs is divided into two real physical waves ϕ_1 and ϕ_2, but the neutron-singularity, which can not be divided, follows on one or the other wave. When the singularity goes on the real wave ϕ_2 it interacts with the detector D_R and triggers it, giving rise to a signal seen by the observer. In the mean time the physical wave ϕ_1 keeps going on its way unaffected, because no physical action was practiced on it.

Suppose know that the detector D_R after being activated sends a signal to a fast neutron gate G, see Fig.2, which opens for a very short time, enough to allow the passage of the empty wave train ϕ_1. In the alternative case when the singularity is carried by the wave ϕ_1, there is no visible physical action on the detector D_R, because the wave without singularity ϕ_2 has no energy to trigger the detection phenomenon. In such a circunstance no signal is sent by D_R to open the gate G which remains closed, therefore the wave ϕ_1 and the singularity can not leave the apparatus.

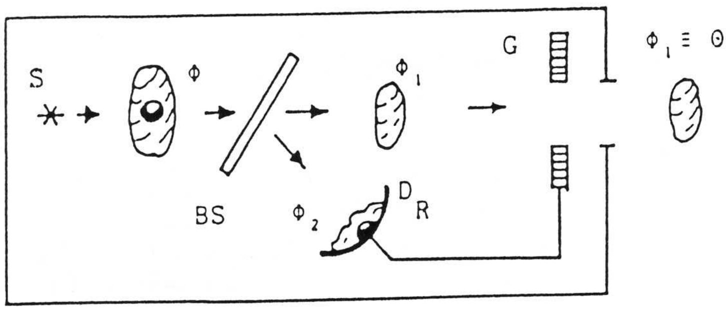

Figure 2. Empty Wave Generator. The source S emits neutrons one by one. The real wave, carrying the singularity, is splitted into two physical waves ϕ_1 and ϕ_2 at the beamsplitter Bs. The neutron-singularity, in the represented case, goes on the wave ϕ_2 triggering the detector D_R. The detector sends a signal to the fast neutron gate G which opens for a very short time just to allow the passage to the empty wave $\phi_1 \equiv \theta$.

The whole experimental apparatus, source S, beamsplitter Bs, detector D_R and fast neutron gate G works like a source of **empty waves**. It is convenient to represent the empty waves by a special symbol θ, because their properties are different from the usual waves with singularity. A common wave can, by the action of its singularity, activate a detector, the empty wave can not. On the other side it is possible that they have different mean lives. May be, following Koh [5], the mean life of wave θ is shorter than that of the common wave ϕ.

Naturally for the Copenhagen school there are no empty waves so nothing leaves the apparatus. This conclusion can be checked easily by placing a detector in front of the empty wave generator. Obviously, the detector shall detect nothing in agreement with the predictions of the Copenhagen and the causal interpretations of the quantum formalism.

The conception of the empty wave generator is founded upon the different meanings given to the wave function by the two interpretations of quantum mechanics. For the Copenhagen school the wave ψ is only a probability function, for the theory of de Broglie, on the contrary, it represents a real physical wave.

3. Detection of Empty Waves

Now we can dispose of a source of empty waves, therefore it is necessary to verify if they are in fact real physical waves. If so, they should be able to induce macroscopic observable phenomena, otherwise they shall be no more than pure methaphysical speculations.

To detect the empty waves, by incoherent wave mixing, one ough to assume the following assumptions:

1 – *The empty waves θ really exist.*

2 – *The singularity is guided by the wave in which is immersed. This wave is the sum of all overlapping waves, even in the case when they come from different sources.*

3 – *There are sources able to emit particles one by one.*

The validity of these hypothesis have already been discussed, in detail, in some other works [6, 7, 8, 9]. The first point is a cornerstone of de Broglie's causal theory. The second is a direct consequency of the first assumption of the reality of the wave θ, which is experimentally proved, for the case of photonic waves. Interferometric experiments, done with independent laser sources, Mandel [10], Radloff [11], show that in fact photonic waves from independent sources interfer. The last assumption can experimentally be fullfiled for most cases. Even for the light case, monophotonic sources, delivering photons one by one, have recently been built [12].

Once these hypothesis assumed the detection of empty waves is based in the following steps:

a) Production of empty waves (empty wave generator).

b) Incoherent superposition, in an interferometer, of empty waves with commom waves, from interpendent sources.

One of the great advantage of the method lies in the fact of being a yes-no type experiment. Whichever the result may be it shall be conclusive, if of course the experiment is carried out correctly. On the other hand the process can be applied, in principle, to any kind of microparticles, from photons, visible domain [6] to γ radiation, electons, neutrons [7], etc.

In what follows only photons of the visible domain shall be considered, nevertheless the method remains essentially the same for the other particles.

Consider Fig.3, where schematically is represented the overlapping of three waves, two empty waves θ_1 and θ_2, coming from the empty wave generator (EWG) with a full wave ϕ. In suh conditions at the detection zone, detector D, three waves overlap and the total resulting wave $\phi_T = (\theta_1 + \theta_2 + \phi)$ shall guide preferentially the photon-singularity to the zones of greater wave amplitude. In the interferential region the singularity shall be guided, not by the wave that initially had carried it, but by the total wave in which it is immersed. Therefore the intensity distribution, predicted by the causal theory shall be

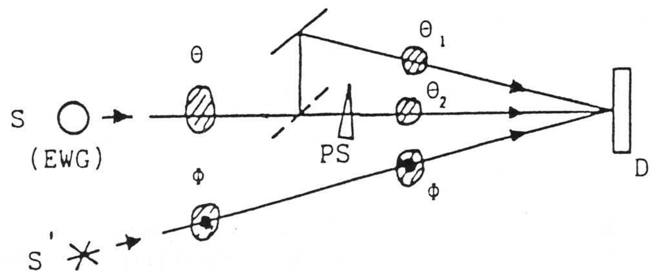

Figure 3. Schematic representation of three waves superposition. The empty waves are coherent, but incoherent relatively to the full wave coming from a different source.

$$I_c \propto |\theta_1 + \theta_2 + \phi|^2, \tag{1}$$

which can be written

$$I_c \propto |\theta_1 + \theta_2|^2 + |\phi|^2, \tag{2}$$

because the θ waves are coherent between themselves, they come from the same source, but they are incoherent relatively to the wave ϕ coming from an independent source S'. Setting, in other to simplify notation, the simplest case of equal wave amplitude

$$|\theta_1|^2 = |\theta_2|^2 = |\phi|^2, \tag{3}$$

formula (2) becomes, after some easy calculation

$$I_c \propto (1 + \frac{2}{3} cos\delta), \tag{4}$$

where δ represents the relative phase of the waves θ_1 and θ_2.

Now, what are the predictions of the Copenhagen school for this experiment. According to this interpretation of quantum formalism empty waves do not exist, so equation (1) must be written simply

$$I_u \propto |\phi|^2. \tag{5}$$

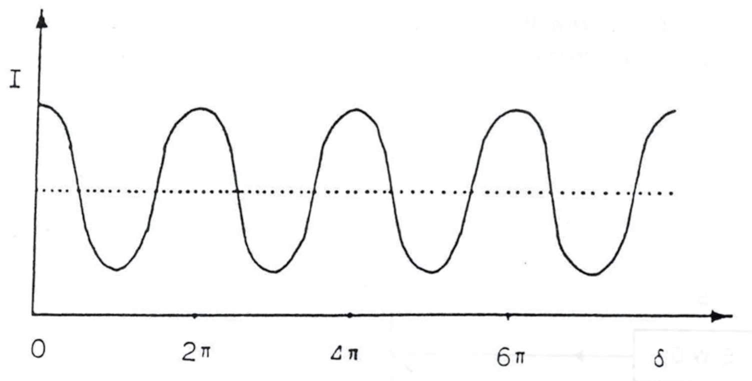

Figure 4. Predicted results: Usual (Copenhagen) dotted line; Causal (de Broglie) solid line.

As is depicted in Fig.4 the difference in the predictions of the two theories is really striking. Usual interpretation predicts a constant intensity distribution, the causal theory expects an interference pattern modulated by the phase of the waves. This phase difference is experimentally controlled by the phase shifting device Ps.

4. A Concrete Proposal of Experiment

Till now, in the proposed experiments, based on the incoherent wave mixing [8], it is necessary to guarantee that the waves coming from the independent sources arrive at the same time at the interference region. Otherwise the waves shall not overlap and, consequently, the experiments shall have no meaning. These conditions are not easy to meet in practice. In fact it is necessary to build special independent sources able to emit particles at the same time [6]. Other process is to sellect, with fast electronic devices [9], only those events when there is a fair superposition, of the different waves, at the interference zone.

In this paper, it shall be presented, in general way, a different process suggested by the methods of optical communications, which does not need the preparation of synchronic sources or coincidence apparatus.

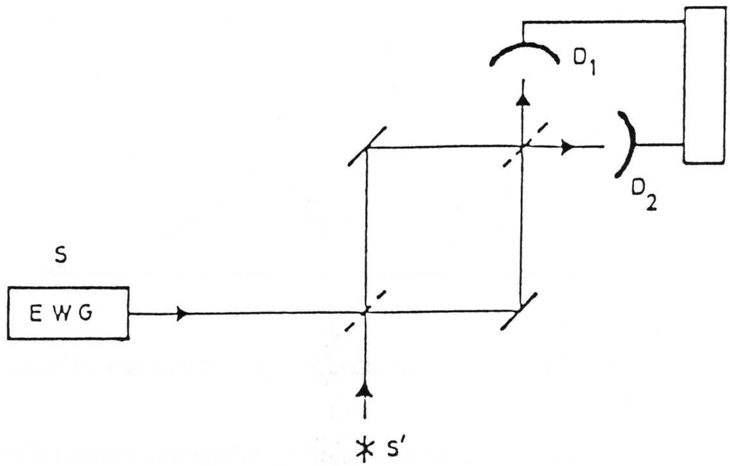

Figure 5. Proposed experiment for incoherent detection of empty waves without coincidence devices or synchronized sources.

In Fig.5 is schematically represented the proposed experiment for incoherent detection of empty waves by the assynchronous method. The apparatus is composed of a Mach-Zehnder interferometer, a photonic source of empty waves S (EWG) and of a steady common photon source S', plus the detecting counting system.

The counting intensity, per second at detectors D_1 and D_2 predicted by the usual interpretation of quantum theory are [6] respectively

$$\begin{cases} I_u^1 = \frac{1}{2} I_0 (1 + cos\delta_\phi), \\ I_u^2 = \frac{1}{2} I_0 (1 - cos\delta_\phi), \end{cases} \tag{6}$$

where I_0 is the total counting intensity per second of the two detectors, and δ_ϕ is the phase difference of the waves ϕ coming from the source S'.

In the causal picture of de Broglie one must also consider the θ empty waves. For the case of synchronized emission [6], these calculations give

$$\begin{cases} I_c^1 = \frac{1}{2}I_0(1 + \frac{1}{2}cos\delta_\phi - \frac{1}{2}cos\delta_\theta), \\ I_c^2 = \frac{1}{2}I_0(1 - \frac{1}{2}cos\delta_\phi + \frac{1}{2}cos\delta_\theta), \end{cases} \qquad (7)$$

with δ_θ representing the relative phase of the θ waves. Setting the experimental conditions so that $\delta_\phi = \delta_\theta$, and inserting those values into equation (7) we have

$$\begin{cases} I_c^1 = \frac{1}{2}I_0, \\ I_c^2 = \frac{1}{2}I_0. \end{cases} \qquad (8)$$

On the other hand fixing the phase of the ϕ waves in $\delta_\phi = 0, \ldots, 2n\pi$, and introducing it into (6) the usual predictions become

$$\begin{cases} I_u^1 = I_0, \\ I_u^2 = 0. \end{cases} \qquad (9)$$

These results show that at the output one the waves are in phase and at the other in phase opposition, so all intensity from the source S' is transmitted, nothing is reflected.

The causal predictions (8) as stated before, are valid whenever, at the interference zone, the waves packets from the two independent sources S and S' overlap, that is when they are emitted at the same time. Although if special precautions are not taken the two independent sources shall emit in a random way. Some times, at the detection region, arrives the full wave ϕ without the corresponding empty wave θ, or vice versa. In such cases no inference about the existence of the empty waves can be made, the predictions of the two interpretations are precisely the same. Under the normal circumstances, some times the sources emit simultaneously others not, in a perfectly random way.

Let n_ϕ be the total number of counts, per second, registered at the two detectors, and n_c the coincidence rate, also per second, between empty and full waves. The number of full waves, per second, detected at the photomultipliers without the corresponding empty waves is $(n_\phi - n_c)$. In such conditions the counting intensity, per second, predicted by the causal interpretation can be decomposed of two parts: One corresponds to the arrivals in coincidence, the predictions, for this case are given by equations (8). The other part regards the cases when there are no coincidence in the arrivals, of the wave packets from the different sources, at the detector, so usual formula (9) holds. Taking in account these two situations the causal predictions shall be

$$\begin{cases} I_c^1 = \dfrac{1}{2}n_c + (n_\phi - n_c), \\ I_c^2 = \dfrac{1}{2}n_c. \end{cases} \tag{10}$$

Let ε be the characterizing coincidence factor for the emission of the two sources, so that

$$n_c = \varepsilon n_\phi, \qquad 0 \leq \varepsilon \leq 1, \tag{11}$$

inserting in equations (10) one gets

$$\begin{cases} I_c^1 = (1 - \dfrac{1}{2}\varepsilon)n_\phi, \\ I_c^2 = \dfrac{1}{2}\varepsilon n_\phi. \end{cases} \tag{12}$$

These are the general causal equations, valid for all cases. If there are no overlapping of the waves ϕ and θ, no coincidence emission $\varepsilon = 0$, those equations (12) transform into the usual ones (9). For the best case, sources emitting at the same time $\varepsilon = 1$, one gets the known equations (8).

Defining Δ as the difference between the countings, per second, at the two detectors

$$\Delta = I^1 - I^2, \tag{13}$$

one shall have for the two interpretations of quantum mechanics:

Usual theory

$$\Delta_u = I_u^1 - I_u^2 = n_\phi. \tag{14}$$

Causal interpretation

$$\Delta_c = I_c^1 - I_c^2 = (1 - \varepsilon)n_\phi. \tag{15}$$

These results are shown if Fig.6 for the particular case of $\varepsilon = \frac{1}{2}$.

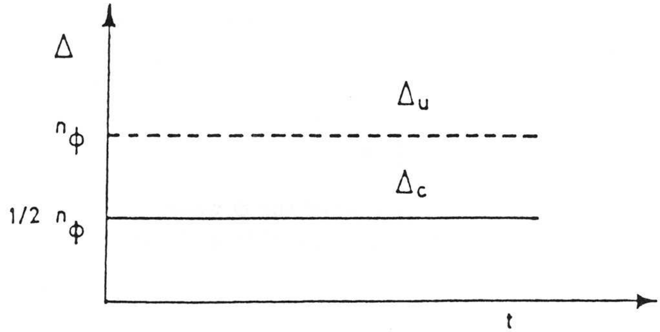

Figure 6. Predictions of the two interpretations of the quantum formalism for the particular case of $\varepsilon = \frac{1}{2}$. Broken line usual theory. Solid line causal theory.

In the case of no superposition between the full and the empty waves, $\varepsilon = 0$, the predictions of the two theories are the same $\Delta_u = \Delta_c$. For different values of the coincidence coefficient $0 \leq \varepsilon \leq 1$, all intermediary cases for Δ, $(0 \leq \Delta_c \leq \Delta_u)$, are obtained. Considering the best situation, sources emitting always at the same time, $\varepsilon = 1$, the difference in the predictions is maximal $\Delta_c = 0$ and $\Delta_u = n_\phi$.

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