Double Slit Experiment Explained by the Principle of Complementary and the Doppler Effect

Mugur B. Răuţ[1]
[1]Public Services Society, 25 Tudor Neculai Street, Iaşi, România
([1]m_b_raut@yahoo.com)

Abstract-In this paper I propose an explanation of the double slit experiment results, considered in a general form, in terms of the Doppler effect, as a consequence of applying the principle of complementarity. It is shown that, if we accept the fact that both particle and wave are manifestations of the same conceptual whole, in the general form of the particle-wave dualism, then the Doppler effect will be a manifestation for both wave and particle, and the double slit experiment will be a qualitative illustration of this fact.

Keywords- *Double Slit Experiment, Particle-Wave Dualism, Copenhagen Interpretation*

I. Introduction

In science, particle-wave dualism concept, in its general form, was built quite late, in the early years of quantum mechanics, in the first half of the 20^{th} century. In reality, the concept is much older and appears for the first time in philosophy, due to Democritus, [1]. In its "restricted" form, referring on the nature of light, Democritus extrapolates the idea that the basis and the entanglement of the matter are atoms, to light, which would be made up of atoms of light. In science, the idea that light would be made up of elementary pieces of matter belongs to Newton, [2]. His contemporary Huygens, [3], brings the issue into a new framework, a wave-like one, which sometime later, first with Fresnel, [4], and then with Maxwell, [5], knows a strong conceptual and mathematical substantiation. So that, even if before the birth of quantum mechanics the dual nature of light it is not yet admitted, the scientific community from all over the world was fully agree that the light has both particle and wave properties.

The discovery of external photoelectric effect by Hertz, [6], did not clarify this matter. But its late explanation due to Einstein, [7], using Planck's ideas concerning the quantum nature of light, [8], practically meant the birth of the dual nature of light idea. Accordingly, light is both particle and wave, simultaneously, and there is no a clear causal relationship between these two manifestations of matter. Not long after this victory for science, in 1924, French physicist Louis de Broglie generalized this idea by postulation to the full spectrum of elementary particles and beyond, [9]. According to de Broglie, not only light exhibits a dual nature of particle and wave, but all elementary particles exhibit the same dual nature. The relative quick confirmation of this hypothesis by Davisson and Germer's experiments, [10], the formulation of Heisenberg uncertainty principle, [11], Copenhagen Interpretation, [12], and finally the advent of the pilot wave theory, [13], practically consolidated the particle-wave dualism idea. We consider it was the concept with the longest evolution in the history of science.

Over time, particle-wave dualism generated some interpretations of quantum mechanics, [14]. Among these interpretations, the one which looks like it has imposed is that proposed by the so-called Copenhagen Interpretation, [15]. According to it, the dual nature of matter is due to the type of experiment which highlights particle features or wave features, and, very strange, sometimes the result of the observation is given by an esoteric influence of the observer. As an example of this statement is the double slit experiment, [16].

We will not describe in details this experiment because it is well-known; we will point out only the details that matter. A remote observer from double slit will always record an interference pattern. While if the observer is in the vicinity of the double slit, he will record only the particles that pass through the two slits.

This strange phenomenon has aroused a lot of interest and fascination, for its elucidation the physicists have all sorts of fanciful explanations. The most common is the one which claims that the observer directly influence the outcome of the experiment, nobody knows how, by just his simply presence and even if he never wants to get some influence. In a way, this is the Copenhagen Interpretation position and the "official" interpretation accepted by physics.

The last craziness seems even more so because it seems detached from a science fiction movie. It is peculiar that if we add a row of two more slits after the first row of slits, the same phenomenon occurs. I mean, a distant observer sees after the second row of slits the interference figures, and even getting closer to the last row he sees only particles. It seems that no matter how many rows of slits are, the observation results are the same. The explanation, hallucinating, especially for the high-cited journal which published it, is that the reality exists only when we observe it and the past is somehow, no idea how, generated by the future. Otherwise the beam would not "know" how to manifest before the next row of slits, or waves or particles, not depending on how many rows of slits we have, [17].

Interesting, but I think the problem would be solved much easier if we try to look at it from the motion perspective.

II. DOPPLER EFFECT HYPOTHESIS

How phenomena occur in this experiment is undoubtedly a problem of movement, a problem of position of the observer towards leaving or coming beam. It is the same as in the Doppler effect case. But this effect is not seen here as in ordinary cases, observing the redshift. If it does exist, then it would be very small, unnoticeable. Instead, different phenomena, depending on the direction of the movement, are seen. If the beam leaves the observer, then it is seen as waves (interference fringes), after it is passing the two slits. However, if the beam is coming to the observer, then it will be seen only as particles. These phenomena not look like a classical Doppler effect, but we can explain them through Doppler effect if we consider that the particle-wave assembly manifest itself as a wave in a case, and as a particle in the other case, according to principle of complementarity. Meaning that both particle and wave they manifest the same as far as the Doppler effect concerns. This effect is specific for particle too, not only for the wave. And when the effect would occur it will be very small, unnoticeable through calculation and other observations, and manifest itself as a phenomenon generated by a wave, as well as a particle.

Indeed, if we start from the principle of complementarity, expressed as the general postulate:

$$\lambda = \frac{h}{p} \ , \tag{1}$$

admitting that the Doppler effect is specific for waves,

$$z = \frac{\lambda_{observed} - \lambda_{emited}}{\lambda_{emited}} = z_{\lambda} \, , \tag{2}$$

for particles and the overall manifestation as particle-wave too, as a consequence of the same principle of complementarity :

$$z = z_{\lambda} = z_{p} = z_{\lambda+p} \, , \tag{3}$$

then from expressions (1), (2) and (3) we get the general expression

$$\lambda_{observed} \cdot p_{observed} = \lambda_{emited} \cdot p_{emited} = h \, . \tag{4}$$

Now, from the expressions (2), (3) and (4) result the quantitative expression for particle Doppler effect

$$z_{p} = \frac{p_{emited} - p_{observed}}{p_{observed}} \, . \tag{5}$$

In the double slit experiment this effect is unnoticeable by calculation, as the wave-like effect also, but in a general case as the one we refer here, it is calculable, for example in astrophysics when we can evaluate the redshift of light that comes from far away. In our discussion z help us to qualitatively understand the phenomena, not for quantitative calculations. The expression (3) must be understood that the overall manifestation as particle-wave dualism, for a single beam, simultaneously is impossible; it is a hypothesis, the principle of complementarity. This means if we have two beams, independent or originated one from the other, there is no possibility to have a simultaneous manifestation of the particle-wave dualism. It is like we have two different experiments running in the same time. This matter of thinking is specific to quantum mechanics due to principle of complementarity. It could generate paradoxes if we use the non-classical way of thinking, because it includes three logical choices: wave, particle and wave + particle. In deterministic way of thinking we are accustom there are only two choices, wave and particle, [18, 19]. In my opinion, in this case we must think classically because we don't know how the third logical choice looks like.

Now, if the observer would be placed somewhat at midway between the coming beam towards him and the same beam that goes from him to a certain target, then, overall, the situation would be described by $z > 0$, in the case the beam is coming towards him, and by $z < 0$ in the case the beam passed the observer.

Considering now the hypothesis (3), then the general situation described above would be equivalent to all possible experimental situations:

$$z_{\lambda} > 0 \, , z_{\lambda} < 0 \tag{6}$$

and

$$z_{\lambda} > 0 \, , z_{p} < 0 \, . \tag{7}$$

It should be understood that (6) and (7) express all experimental tendencies that particle-wave dualism can be observed in the case $z > 0$ and $z < 0$. Calculable or not, in other words these trends can be highlighted by quantitative or qualitative experiments, they express rather the kind of phenomenon through which a tendency or another is observed. Therefore (6) should express only the case corresponding to the coming and going wave to the observer, for example the so-called one-slit experiment, a qualitative experiment. The fact that we cannot measure the redshift doesn't mean that it is not exist. There are experiments that can measure the redshift, quantitative experiments, those in which the light comes from a large distance. On the other hand there is the situation when you cannot discern between particle and wave. An example for this situation is when redshift can be interpreted as a delay of particle also; in this case (6) is equivalent to $z_{p} > 0$, $z_{p} < 0$.

Undoubtedly, the double slit experiment would fit the situation (7), as a qualitative experiment, in the Doppler effect sense. We must admit the possibility that the situation (7) can be illustrated as a quantitative experiment too, in the Doppler effect sense. Perhaps, if the beam would come from a large distance and go to a large distance, then we have this situation. In the case of interest for us, the double slit experiment, when the observed beam comes to observer, he observe only a corpuscular phenomenon, while after it passes the observer, a wave-like phenomenon is observed only. This fact is due to the manifestation of the conceptual whole, the wave-particle dualism, in terms of Doppler effect. I see the quantity $z_{\lambda+p}$ as a constant, not in a mathematical way, but from a physical behavior perspective. If $z_{\lambda+p} = z_{\lambda} + z_{p}$, $z_{\lambda+p} > 0$ and $z_{\lambda} > z_{p}$ then the dualism wave-particle manifest itself as a wave because $\lambda_{observed} > \lambda_{emited}$. The observed wave character of the dualism whole is more pronounced than the particle-like one and the dualism manifest itself only as a wave. If $z_{\lambda+p} < 0$, $z_{p} < 0$ and $|z_{\lambda}| < |z_{p}|$, then the dualism wave-particle manifest itself as a particle because $p_{emited} < p_{observed}$. The observed particle character of the dualism whole is now more pronounced than the wave-like one. This is the natural manner in which the conceptual whole, the wave-particle dualism, is manifesting itself. The problem occurs when we try to observe and measure it. In one-slit experiment we don't see anything, but this doesn't mean that the conceptual whole, the wave-particle dualism, is not manifesting itself in a natural manner. Thus, the double-slit experiment is a fortunate example of the natural manifestation of the wave-particle dualism. But in most experimental cases we observe and measure only z_{λ} because of the dual character of the matter and because we presume that only wave can be characterized by Doppler effect.

III. INTERPRETATION

The Copenhagen Interpretation of quantum mechanics is generally correct. The observer influences the observation only through the type of experiment which is chosen. There is no esoteric observer influence on observation, there is only Doppler effect. The reality exist before observation, it is not created after observation. But it depends on how observation is made. If it would done simultaneously in both places, at the source and at the target, then both aspects will be seen, particle and wave, in the same time. Instead, the two aspects of matter can be seen only in succession because they are occurring in different places, in our case because of the Doppler effect. For this reason reality is preexisting, since it is not created by Doppler effect; the Doppler effect is only a manifestation of the existing nature. Apparently Afshar's experiments contradicts this statement, [20], but we consider there are two beams involved in this case. It is like we have two experiments running in the same time, each one having its own results.

The conceptual whole particle-wave does not "know" in advance how to behave, as a particle or as a wave, only the observer sees one way or another, depending on the position of the beam with respect to him, in accordance with the Doppler effect.

Particle and wave are aspects of a conceptual whole. They occur simultaneously, even if we cannot put in evidence experimentally this fact. We cannot say also that one creates the other. For example, if we consider the particle as being primordial, and this particle generating waves (like ripples generated in water by a ship) through a kind of "friction" with the quantum vacuum, then we have a bizarre situation. If the particle would be the source and the wave what that source "emit", then the wave would be generated by the particle through Doppler effect. But, unfortunately, the reasoning presented in the previous section does not allow this interpretation.

Particle and wave cannot observationally manifest in the same place, at the same time, due to Doppler effect. Because of this effect particle and wave are manifested only successively in different places.

IV. CONCLUSIONS

In this paper we propose an explanation for the double slit experiment phenomenon, considered into an aggregate form, from a Doppler effect perspective. It is shown that if we accept that both particle and wave form a conceptual whole, or unit, expressed through a general particle-wave dualism postulate, as a consequence of applying the principle of complementarity, then the Doppler effect will occur for both wave and particle respectively. It results then an interpretation of quantum mechanics according to which the observer influence the observation only by the type of experiment he conceive. Meaning that the observed phenomena are in different places, sequentially not simultaneously.

However, there are experiments in which we can observe both manifestations, particle and wave, simultaneously. They take place for different observers and different locations. Double slit experiment, in its classic version, is such an experiment, if there would be two observers. If, however, an observer might be found in two places simultaneously he could see the particle–wave dualism simultaneously in different places. It follows that what we observe is somehow consistent with our observational limits; the observer is not moving at some relativistic speed. In normal laboratory conditions these observations may shock you, but in reality, if these observations were done simultaneously, there would be nothing shocking in it. We couldn't conclude that the observer influence somehow in an esoteric manner the output observations. The observed phenomena are due to only the Doppler effect.

REFERENCES

[1] J. Barnes, The presocratic philosophers, Routledge Revised Edition, 1982.

[2] I. Newton, Opticks, or a treatise of the reflections, refractions, inflexions or colors of light , Palo Alto, California, 1998.

[3] F. Trager, Springer handbook of lasers and optics, Springer Science and Business Media, 2012, pp. 5.

[4] H. Crew, The wave theory of light: Memoires by Huygens, Young and Fresnel, American Book Co., 1900, pp. 81-144.

[5] J. C. Maxwell, A treatise on Electricity and Magnetism, Clarendon Press, Oxford, 1873.

[6] D. Baird, R. I. Hughes and A. Nordmann, Henrich Hertz: Classical physicist, modern philosopher, New York, Springer-Verlag, 1998, pp.53.

[7] F. W. Sears, M. W. Zermansky, H. D. Young, University physics, 6th edition, Addison-Wesley, 1983, pp.843-844.

[8] R. A. Serway, Physics for Scientists and Engineers, Saunders, 3rd edition, 1990, pp. 1150.

[9] D. H. Menzel, Fundamental Formulas of Physics, vol I, New-Jersey, Prentice-Hall, 1955.

[10] C. J. Davisson and L. H. Germer, Reflection of electrons by a cristal of Nikel, Proc. of the Nat. Acad. of Sci. of U.S.A. **14** (4), 1928, pp. 317-322.

[11] W. Heisenberg, The physical principles of the quantum theory, University of Chicago Press., 1930, pp. 20.

[12] J. Mehra and H. Rechenberg, The hystorical development of quantum theory, Springer-Verlag, 2001, pp. 271.

[13] A. Valentini, On the pilot-wave theory of classical, quantum and subquantum physics, Ph. D thesis, International School for Advanced Studies, Trieste, 1992.

[14] R. Omnes, The Interpretation of Quantum Mechanics, Princeton Univ. Press, 1994.

[15] W. Heisenberg, Physics and Philosophy-The Revolution in Modern Science, New York, Harper & Row Pub. Inc., 1962, pp. 14-26.

[16] A. Platnisky, Niels Bohr and Complementarity. An Introduction, Springer, 2012, pp. 75-75.

[17] A. G. Manning, R. I. Khakimov, R. G. Dali and A. G. Truscott, Wheeler's delayed-choice gedanken experiment with a single atom, Nature Physics **11**, 2015, pp. 539-542.

[18] T. A. Brody, On Quantum Logic, Foundations of Physics **14**, 5, 1984, pp. 409-430.

[19] N. Bohr, Atomic physics and human knowledge, New York, Wiley, 1958, pp. 66-67.

[20] S. S. Afshar,Violation of the principle of complementarity, and its implications, Proc.of SPIE **5866**, 2005, pp. 229-244.