Phase pseudowaves and interference on a resonator: to the question of the nature of light and quantum interference

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The de Broglie's hypothesis that every particle is associated with a fictitious phase wave has a real, classical analog that we call "phase pseudowaves". Such pseudowaves are inherent to beams of ordinary particles whose parameters vary as periodic functions. Through impacting the behaviour of common resonators, phase pseudowaves create interference patterns reproducing unordinary features of light and quantum interference in the double-slit experiment. Sensors containing a resonant tank circuit and measuring the wave amplitude respond in the same way to ordinary waves and phase pseudowaves. It may prove to be the case that light interference transpires to be the superposition of waves, wave packages or phase pseudowaves, which do not interact in a "normal" manner on a resonator.

Keywords: phase pseudowave, interference on a resonator, de Broglie's waves, double-slit experiment, light interference, quantum interference

1. Introduction

In 1923 the French physicist Louis de Broglie introduced the term «fictitious phase wave» as a means of describing wave fields of an unknown nature («a simple periodic phenomenon») associated with any quantum particle including photons. De Broglie put forward a hypothesis predicting that this oscillating process must have three basic features:

- it is described by a wave equation;
- it carries no energy (fictitious waves);
- at any time the phase of the internal oscillating process occurring inside a microparticle must coincide with the phase of this fictitious wave.

De Broglie developed the concept of fictitious phase waves in order to explain a number of quantum properties of both microparticles and light. Similar to Einstein, de Broglie thought that light quanta were particles; he even preferred to call them «atoms of light».

De Broglie suggested that

- a microparticle is associated with an internal periodic phenomenon whose frequency in the rest frame of the particle is associated with the rest mass of the particle as follows:

$$mc^2 = h\nu_0; \tag{1}$$

- a microparticle is accompanied by a field where the oscillatory phenomenon takes place and this phenomenon is described by a fictitious (i.e. carrying no energy) phase wave;
- the velocity of the particle is inversely proportional to the phase velocity of the fictitious wave:

$$\upsilon = c^2/V. \tag{2}$$

De Broglie showed that equation (1) is relativistic ally invariant due to equation (2). That is why the frequency of the phase wave observed in an inertial frame of reference depends on both the velocity of the particle and its mass.

The fictitious phase wave, occurring in the field of a quantum particle, causes diffraction and interference phenomena. De Broglie suggested that diffraction can be explained in terms of the impact produced by the phase wave on the trajectory of the mass particle. In other words, the phase wave behaves in respect to the mass particle as a pilot wave.

De Broglie has described the quantum particles interference process using «light quanta» as an example as follows:

«*Some atoms of light pass through the holes and diffract along the ray of the neighbouring part of their phase waves.* ***In the space behind the wall, their capacity of photoelectric action will vary from point to point according to the interference state of the two phase waves which have crossed the two holes.*** *We shall then see interference fringes, however small may be the number of diffracted quanta, however feeble may be the incident light intensity.* ***The light quanta do cross all the dark and bright fringes; only their ability to act on matter is constantly changing.*** *This kind of explanation, which seems to remove at the same time the objections against light quanta and against the energy propagation through dark fringes, may be generalized for all interference and diffraction phenomena*» (the text is highlighted by us) [3].

The hypothesis contained within this citation, explaining the phenomenon of interference, revolutionizes our understanding of this phenomenon. According to de Broglie, light interference should be considered as a redistribution of photoelectric energy rather than a redistribution of the energy of the electromagnetic field.

This is the most detailed definition of phase waves or internal periodic motion in the entire works of de Broglie. In the Conclusions section of his doctoral thesis, de Broglie wrote that this theory should be considered as a kind of schematic theory whose physical content is not entirely specified [4].

De Broglie's hypothesis about the nature of quantum interference was not supported by his contemporaries and was subsequently forgotten about. The original spatial model, as a fictitious wave associated with every particle, has been transformed into a matter wave packet whose group velocity coincides with the velocity of the particle. Today, de Broglie's matter waves are interpreted in this manner. In the case of light quanta, de Broglie waves are seen as electromagnetic waves.

However, not only quantum particles, but also ordinary particles – i.e. particles whose motion is described by classical mechanics – can be carriers of fictitious phase waves. The only difference between these fictitious waves and those described by de Broglie is that the former are represented by coherent particle beams rather than solitary particles.

Here we define the term «coherent» as capable of generating interference effects under certain conditions. These effects are due to certain dependencies between the parameters of their component particles, one of which is described by a periodic function. We shall define the term «coherence constraints» as the entire set of such dependencies needed for the generation of interference effects.

As ordinary particles we regard free corpuscles, linked systems containing several corpuscles and also solutions (a wave packet that maintains its shape while it travels at constant speed).

In order to make a distinction between the pseudowave phenomenon displayed by ordinary particles and de Broglie's wave inherent solitary quantum particles we shall call the former «phase pseudowave».

Phase pseudowaves can be associated with beams of any kind of particles including ordinary bullets fired out of an ordinary gun with a random distribution of time intervals between shots.

Pseudowaves displayed by ordinary particles allow a simple and natural simulation of certain quantum interference effects. In particular, this is true in the case of the interference of solitary particles behind an opaque screen with two slits.

Feynman called this effect an «*element of the mysterious behavior in its most strange form… phenomenon which is impossible,* ***absolutely*** *impossible* <highlighted by the authors>*, to explain in any classic way*» [5]. We do not know whether we succeeded in explaining this effect, but it is certainly possible for the effect to be faithfully reproduced in intricate detail.

2. Mechanical phase pseudowaves

Fig. 1 shows a source generating a coherent beam of transversely oscillating particles. Each of these particles is a harmonic oscillator made up of two massive balls connected to a massless spring. They are fired out of a flattened, ellipsoidal gun muzzle at equal speeds so that the balls begin to oscillate in the transverse direction about the center of mass with the same frequency, initial phase and amplitude. For illustrative purposes, let us assume that the black balls are more massive than the white ones and so the oscillations of the former can be ignored.

The wavy dashed line shows the time-independent common trajectory of the white balls. This line can be also regarded as a graphic depiction of a phase pseudowave associated with the beam. In this case, the phase velocity of this kind of pseudowaves is equal to the velocity of the source.

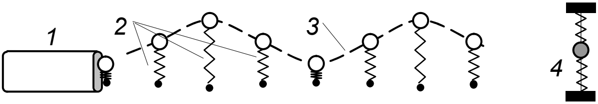

Fig. 1. Modulator source – *1*, transversely oscillating particles – *2*, common trajectory of white balls – *3*, detector of phase pseudowave – *4*

Fig. 1 shows a stationary (motionless) source and therefore the phase velocity is equal to zero. This source can be modified by adding a device changing the initial phase of particles according to a specific distribution function. In the latter case, we can obtain any desired value of phase velocity, both in the direction of the motion of the beam and in the opposite direction.

In order to observe the effects of interference upon the phase pseudowaves, one must use a special detector, namely a resonator, i.e. an oscillating system that accumulates the energy of the oscillations thanks to the effect of resonance upon the driving force.

In fig. 1 the resonator detector consists of a magnetized ball sliding along a stretched string with two fixed springs at the ends. The white balls are made of a ferromagnetic material, while the springs as well as the black balls are made of a diamagnetic material. In the event of a resonance, the driving force (generated by the white ball and acting on the resonator ball) forces the resonator ball to oscillate about the equilibrium point with the same phase and frequency as those of the phase pseudowave. Other harmonics caused by the oscillations of the driving forces produce an impact on the resonator in such a manner that one can use a random phase approximation. Each particle in the beam is a carrier of the phase pseudowave only for so long as its motion is consistent with the coherence constraints. In the case shown in fig. 1 these coherence constraints include the following: equality in linear velocity, the same direction of motion, as well as equality of frequencies, the same direction, equality of amplitudes and initial phases of the oscillations. Alterations to any of the afore-mentioned parameters characterizing the motion of an individual particle will result in the exclusion of the particle from the array of pseudowave carriers.

3. Electric phase pseudowaves

Our further analysis of the properties of phase pseudowaves deals with electric pseudowaves carried by a coherent beam of ordinary bullets (here we ignore the effects of gravity). As a source of such bullets, one can use a multi-firing gun with an AC high voltage source attached to its barrel.

The electric charge carried by a bullet fired from the gun follows a sinusoidal wave pattern:

$$q(r,t)=A\sin[\varphi_0+\omega(t-r/\upsilon)]. \tag{3}$$

Where: υ is the velocity of the bullet; r is the distance between the bullet and the end of the gun barrel.

The distribution (3) of electric charge of the bullets fired from the gun can be regarded as en electric phase pseudowave. As the charge of a bullet does not change over time, the phase velocity of this pseudowave is equal to zero.

As a detector, one can use an ordinary widespread device for detection and measurement of parameters of electromagnetic waves. It is made from an oscillating electric circuit connected to an external antenna and a device for measuring the amplitude of the voltage between the plates of the condenser. The eigenfrequency of this circuit must be close to the eigenfrequency of the phase pseudowave or one of its harmonics.

The electric charges of the bullets induce an electromotive force in the antenna, and this force in turn induces circuit oscillations with the frequency and phase of the pseudowave. It means that the system's oscillations are synchronized by an external periodic force with the capture of the phase and frequency of the external force.

The fact that the intervals between bullet shots are randomly distributed is of no importance. The periodicity of the action of the electric force is due to the electric charges of the bullets. Of course, the time interval between shots need not exceed the time of the attenuation of oscillations in the circuit.

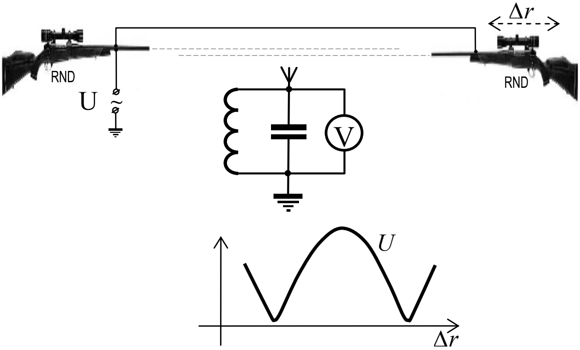

Fig. 2. Excitation of the oscillating circuit by solitary shots from two guns and the curve showing the amplitude volt-age in the circuit versus the position of the second gun

Fig. 2 shows the mechanism of interference of phase pseudowaves in a case when the electric resonant circuit is influenced by the electric charges of bullets fired from two different guns connected to the same AC high voltage source. In order to change the phase shift of the pseudowaves at the point of the antenna, the second gun is movable.

Those phase shifts, which are multiples of π and 2π, correspond to interference extremums. In case in-phase action is produced by the antenna capturing phase pseudowaves, the peak voltage in the circuit hits its maximal value; if the pseudowaves produce their action in phase opposition, the voltage reaches its minimum.

If the space between the two opposite guns is filled with independent oscillatory circuits placed at some distance from each other (fig. 3), the distribution of the amplitudes of auto-oscillations will be typical of that for standing waves with clearly manifested nodes and antinodes.

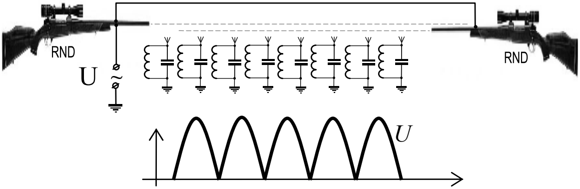

Fig. 3. Interference on resonators of two opposite phase pseudowaves result in emergence of a standing wave

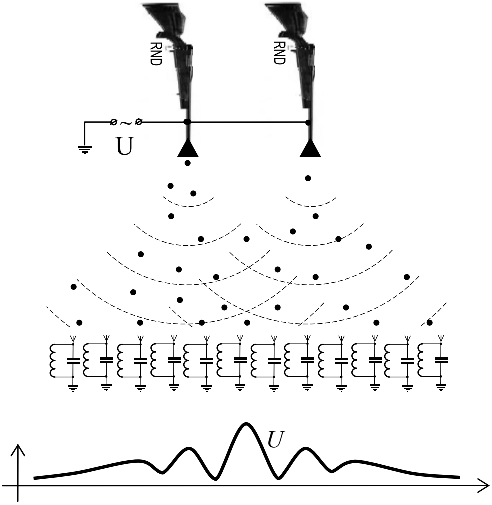

Fig. 4. Interference of phase pseudowaves in divergent coherent beams

Fig. 4 shows interference of two phase pseudowaves in diverging waves. A source of coherent beams emitting particles homogeneously in all directions creates a spherical phase pseudowave.

Diverging coherent beams with trajectories of particles (curved due to the action of obstacles) reproduce the effects of diffraction. Fig. 5 shows a magnetized ball located in the center of a diverging beam of ferromagnetic bullets. The action of the attractive magnetic forces leads to curvature of the trajectory of the particles in the beam and diffraction of the phase pseudowave associated with the beam. The diffraction of the pseudowave is manifested in the production of an interference pattern behind the ball, which can be observed with the use of an electric resonant circuit or a spatially-distributed resonant circuit system.

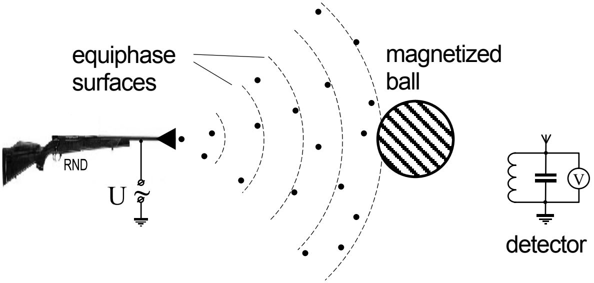

Fig. 5. Diffraction of a phase pseudowave and emergence of a white spot in the center of the "shade" of a magnet-ized ball

Thus a coherent beam of ordinary corpuscles is capable of reproducing the results of the experiments of Delisle (1715) and Arago (1818) who observed a white spot in the center of the shadow of a circular opaque object.

4. Double-slit experiment

Fig. 6 shows a standard diagram of a two-slit experiment. Source 1 emits a diverging particle beam in the direction of screen 2 which is made of impermeable opaque material. There are two vertical slits (3 and 4) in the screen and each of them produces a secondary diverging beam. The secondary beams hit the second screen (5), which is parallel to the first screen and contains a particle detector (6).

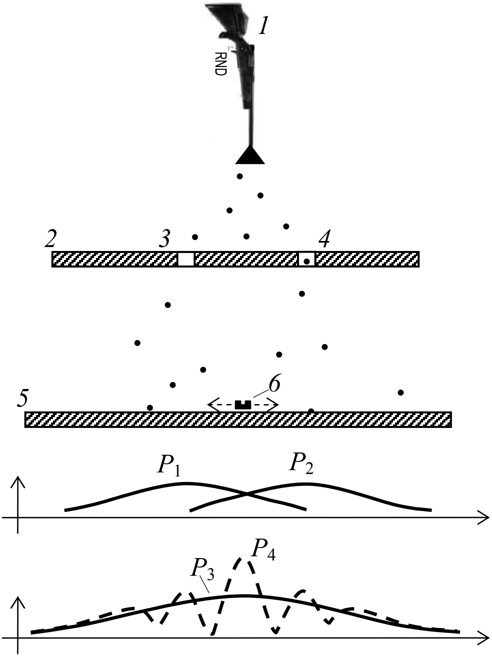

Fig. 6. A standard diagram of a double-slit experiment and the distribution of probabilities of detection of the particles in the case of one open slit – P_1, P_2 and two open slits – P_3, P_4

The P_1 and P_2 curves are the curves of the density of probability to find the particle at certain points on the screen if one of the slits is shut. The shapes of these curves are similar for both ordinary particles and quantum particles. If both slits are opened, the probability distribution for quantum particles in the case of quantum particles follows curve P_4 and in the case of ordinary particles follows curve P_3. It has been discovered that attempts to identify the quantum particle passing a slit result in the disappearance of the interference effect leading to the probability distribution P_3.

The interference of solitary quantum particles has been observed many times in the case of photons [6, 7], electrons [8], neutrons [9], atoms [10, 11] and even molecules [12].

In the double-slit experiment, quantum particles simultaneously manifest several effects which seemingly cannot be explained by classical physics. First of all, although the interference effect is clearly manifested, it remains unclear what the nature of the interfering objects is. Secondly, the effect of interference emerges even in the case of solitary quantum particles. In the last case, a particle passing through a slit «cannot know» whether the second slit is opened or closed and where the interference troughs and peaks are located. Finally, the attempts to determine which slit a particle passes through reduce the capacity of the particle to produce interference patterns.

However, the concept of interference of phase pseudowaves on a resonator allows for a new interpretation of the quantum interference in the double-slit experiment. The afore-mentioned effects cannot be explained by classical mechanics alone in the case when the detector’s sensor is not capable of changing its state depending on the state of the particles captured by it earlier. If the particle beams are coherent and the detector's sensor is a resonator, then all of the peculiarities regarding the quantum interference in the double-slit experiment can find a simple and natural explanation.

In order to observe quantum interference, one can modify the experimental apparatus shown in fig. 6 by positioning an AC voltage source on the gun barrel and using an electric resonant circuit as a detector. The voltage source will make the beam coherent and endow it with the property of wave-corpuscle duality. In this case, each of the slits will be a secondary source of a coherent beam. As a result, the physical situation behind the screen will be equivalent to that shown on fig. 6 and the curve of the voltage amplitude in the resonant detector will correspond to curve P_4.

A specific feature of quantum interference is the disappearance of the interference pattern if one attempts to determine which slit a particle passes through. In the case of bullets, the interference pattern disappears even if only one of the coherence constraints is violated. In this case, such an effect will lead to a change in the bullet's electric charge or velocity by a random value.

5. Wheeler's delayed choice experiment

One possible explanation of the effect of interference in double-slit experiments – if quantum particles do not pass through the areas of the destructive interference – is the assumption that there exists some hidden (additional) parameters causing this effect. Although unknown today, these parameters determine whether a quantum particle will behave as a corpuscle or a wave.

In order to check this hypothesis, Wheeler proposed to modify the double-slit experiment through adding the possibility of delayed choice when identifying the slit [13]. The delayed choice means that the procedure to determine which slit the particle has passed through is carried out after the particle passes the slit.

According to quantum theory, the identification of the slit that a particle passed through must lead to the loss of the particle's capacity to produce interference patterns independently of the moment when the decision regarding the measurement and identification of the slit was made. According to widely-held views regarding the possibilities offered by local theories with hidden (additional) variables, the identification of the slit after the particle passes through it cannot disturb the effect of interference if the particle behaves like a corpuscle or a wave. The only exception is in cases where the particle simultaneously consists of a corpuscle and a wave. The de Broglie's theories of pilot wave and double solution and Bohm's theory [14] endow particles with such properties.

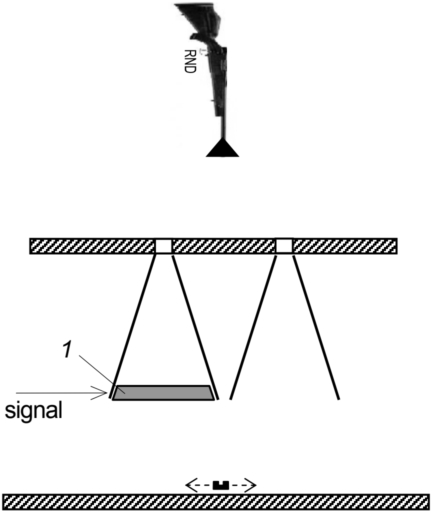

Fig. 7. Modification of the double-slit experiment enabling a delayed choice

Fig. 7 shows a possible variant of modification of the double-slit experiment, meeting the assumptions of the delayed choice idea. After particles pass through the slits, they enter long isolated sleeves. In one of the sleeves there is a commuting device *1* which puts a label on the passing particle after a special signal. The signal is given randomly after the particle enters the sleeve, i.e. after the particle passes through a slit. The design of the particle detector enables it to determine whether the particle is labeled.

According to quantum theory, any label allowing for identification of the slit the particle has passed through deprives the particle of its capacity to produce interference patterns independently of when the particle has been labeled. In the case of the interference of phase pseudowaves, a label deprives the particle of its capacity to undergo resonance as a result of interaction with the detector («capacity to produce interference patterns») only if the coherence constraints are violated.

In 2007, an experiment for measuring the brightness distribution of the interference images emerging when solitary photons pass through the slits designed in accordance with the delayed choice idea was carried out [15, 16]. In this experiment researchers have used a Jamin interferometer (a kind of Mach-Zehnder interferometer) instead of a screen with two slits; however in the context of this article this fact is not important.

The experiment showed that the «label» deprives the photon of its capacity to produce interference patterns as predicted by the quantum theory. However these labels, – i.e. rotation of the plane of oscillations of the electric vector by 90° – violate coherence constraints. That is why the result of this experiment coincides with the results of its analog for phase pseudowaves.

6. Phase pseudowaves and stable orbits

A coherent beam carrying a phase wave can consist of even one particle if this particle moves along a closed pathway. The motion of an ordinary particle around an attractive center in a spatially-distributed system of stationary oscillators can be stable. The precondition for such a motion is that the frequency of the phase wave must coincide with the eigenfrequency of the oscillations of the oscillators. The orbital stability is due to the resonance characteristics of the interaction between the particle and the oscillators.

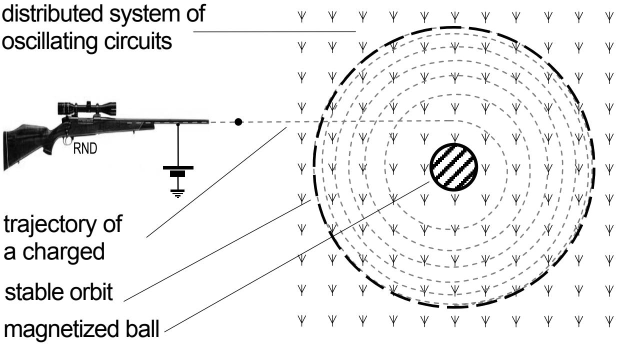

Fig. 8. Emergence of a stable orbit whose length is a multiple of the length of the phase wave

Fig. 8 shows such a situation. An electrically-charged ferromagnetic particle travels closely to a magnetized ball and then begins to move around the ball along a diverging spiral. In the space around the ball, there are stationary antennas connected to independent electric resonant tank circuits. The size of the antennas and the density of their distribution enable them to ignore the probability of collision between the particle and the antennas.

The charge of the particle induces electric oscillations in the resonant circuit. If the radius of the spiral changes only slightly from one spiral turn to another, the particle interacts many times with all of the oscillators of the distributed system with a period that is equal to the time taken for the particle to complete one revolution around the ball.

As the spiral diverges, this period increases. When the frequency of the action caused by the induced electromotive force is close to the eigenfrequency of the resonant circuits, it triggers a resonance. In the latter case, while traveling near an antenna, a particle interacts with the maximal electric charge (of the opposite sign) accumulated on the antenna. The attractive force acting between the electric charge of the particle and the electric charge accumulated on the antenna is the factor, which stabilizes the particle's trajectory, transforming it into a closed orbit.

This example demonstrates the piloting capacity of phase pseudowaves, i.e. their capacity to shape the trajectory of those particles which carry them. A particle moving along a stable orbit is at the same time a carrier of a phase pseudowave whose length is a multiple of the length of the orbit.

7. Light interference is the interference on a resonator

Today the interference of light is defined as «spatial redistribution of energy of light radiation in the imposition of two or more of the light waves, a special case of the general phenomenon of wave interference» [17]. This definition contradicts a number of specific properties of light interference, which do not exist in the case of ordinary mechanical waves or wave packets.

First of all, light waves do not scatter on each other and do not leave any traces of any influence on each other outside the interference zone. Secondly, light quanta produce interference patterns in the double-slit experiment even if they travel individually, one at a time.

Each of these properties together with the idea that interference is a kind of redistribution of energy of the light field disagree with the basic principles of classical physics. For example, in the case of the overlapping of two identical coherent light beams (see fig. 9) under a small angle, where

$$\alpha = \frac{wavelength}{beam\ width} \tag{4}$$

the interference image theoretically need not be accompanied by redistribution of the energy of the light field, although in this case the energy conservation law seems to be violated [18, page 91].

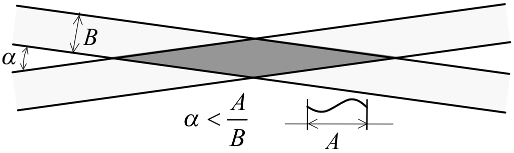

Fig. 9. Two light beams crossed at a small angle. At the intersection region the energy of the light field is either increased or decreased

One more paradox of this kind is described below. It arises from the following experimentally-discovered property: *propagation of a light beam is independent of the fact of whether it crosses through other light beams or not* [18, page 59].

The properties of light interference can be naturally explained if the observed interference patterns are nothing more than a specific feature of the photo effect. Two non-interacting light waves or phase pseudowaves associated with photon beams produce an effect on the same bound electrons, changing the probability of absorption of a photon by an electron.

If we assume that light interference is a special case of interference of phase pseudowaves on resonators, all paradoxes disappear. In this case, the dark area corresponding to the destructive interference is nothing more than a trick of vision or an optical illusion. Any light beam will become invisible if one shifts the phase of oscillations of the electric vector of every second photon in the light beam on π.

Of course, various photodetectors do not detect any photons in the dark area corresponding to the destructive interference. However, all of these photodetectors – from photo plates up to photomultipliers and biological photoreceptors – employ the same type of sensors. In each case, such an element is a high-Q oscillating system consisting of an atomic nucleus and a bound electron.

It is well known that photons are wholly absorbed by atoms. There are good reasons to assume that for the absorption by such a resonant system of all of the energy of the photon, the system must be preliminarily adjusted to respond to the frequency, phase and direction of the oscillations of the wave field that are absorbed. Such an adjustment is made possible only through the synchronization of the self-oscillations of the atom in the process of its interaction with those photons which have passed earlier.

Similar reasoning is valid in the case of interference of other quantum particles.

The synchronization of the excited atom by traveling photons allows for an explanation of why natural light emitted by a luminous point – i.e. a group of excited atoms located close to each other – is coherent. Due to the fact that a photon's width may be several times larger than the size of an atom, the traveling photons synchronize groups of atoms rather than solitary atoms.

8. Experimental methods

One can propose several independent methods for experimental testing of the nature of light interference:

- comparison of intensities of beams of quantum particles in the zones of interference extremums via indirect methods; in particular, in case of light – via methods not employing photoelectric sensors;
- determination of the maximum amount of delay between the passage of the particles in a beam, still allowing for observation of an interference pattern;
- check the possibility of the reflection of light spots by a small mirror that is placed in the zone of destructive interference or the possibility of the light passing through a hole in an opaque screen made in this place;
- experiment using the modified Mach-Zehnder interferometer with a symmetric semi-transparent mirror.

If the interference of light leads to redistribution of photoelectric action, the mirror surface must reflect and an absolutely black body must absorb the same number of photons, both in the area corresponding to the destructive and constructive interference.

In order to check these results, one can compare the values of the light pressure on an opaque body, positioned in areas of constructive and destructive interference, or one can compare the values of the body temperature in this areas.

Below is a description of two simple optical experiments which allow for checking the nature of light interference.

Let us assume that we have an opaque screen, which ideally absorbs the light field and two beams of coherent monochromatic light, producing an interference pattern on the screen. In the dark area of the destructive interference we shall make a hole in the screen (fig. 10), or place a small mirror there. As the size of a dark area can be much greater than the light wavelength, the effects of diffraction can be ignored.

Let us place an ordinary photodetector behind the screen in the case of the hole and before the screen in case of the mirror. It must be placed outside the zone where the two light beams overlap. The position of the photodetector should meet only the following constraints: when the first light beam only is switched on, the photodetector should be illuminated; when only the second light beam is switched on, the photodetector should not be illuminated, i.e. continue to be in the dark.

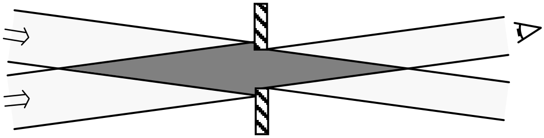

Fig. 10. Light beams pass through the hole in the screen located in the interference trough

In the case of the interference of phase pseudowaves on a resonator, when the second light beam is switched on, the switching on of the second light beam cannot destroy and remove the light field of the first light beam reaching the photodetector.

According to the wave theory of light and quantum theory, when both light beams are switched on, all the energy of the interfering beams (according to the definition of the interference of light beams) is contained outside the hole in the screen and is absorbed by the latter. That is why no energy is left for illuminating the photodetector.

The interference of phase pseudowaves can be distinguished from quantum interference by the disappearance of interference effects due to the surpassing of a certain time interval between the passages of individual particles in the beam. In the case of quantum interference, no limitation is imposed on the delay time, although phase pseudowaves can produce interference patterns only during the period when the resonant element of the detector «keeps in memory» the condition of the phase pseudowave.

A standard Mach-Zehnder interferometer has semi-transparent mirrors made of a transparent dielectric plate whose surface is coated with a thin layer of metal. The asymmetry of this mirror is manifested as follows.

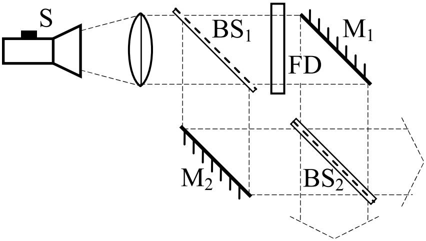

Fig. 11. Mach-Zehnder optical interferometer with a symmetric semi-transparent mirror (BS2) and a phase delay plate – FD

The reflection of the light beam from the metallized surface at the air side is accompanied by a phase shift of a half-wavelength (reflection or refraction at the surface of a medium with a higher refractive index). The reflection of the light beam from the metallized surface at the plate side is not accompanied by a phase shift (reflection or refraction at the surface of a medium with a lower refractive index). That is why in the absence of a phase delay in FD at one of the interferometer's outlets, the reflected beam is recombined with the other beam which has the same phase; at the other outlet it is recombined with the second beam in phase opposition.

The modified Mach-Zehnder interferometer with a special (symmetric) semi-transparent mirror must show an interference effect that is not accompanied by redistribution of the energy of the light field (fig. 11). The use of a symmetric semi-transparent mirror results in equal phase shifts for both reflected light beams. As such, mirror one can use either semi-transparent foil without any dielectric plate or semi-transparent foil placed between two identical plates. As the boundaries of the reflected beams do not coincide in this case, the width of the foil must be a multiple of the wavelength.

According to our model of phase pseudowaves and classical wave theory of light, the intensities of the light field at both outlets of the interferometer must always be equal independently of the phase shift. The intensity of the beams must continue to depend on the phase shift varying from maximums to minimums according to the cosine law.

9. Conclusion

The details of the phenomenon of light interference coincide with the details of the effect of adding oscillations of non-interacting waves, coherent beams of wave packages or phased pseudowaves on a resonator. One might better call this effect «interference on a resonator».

This article deals with the interference of phase waves in beams of corpuscles. A similar phenomenon can be observed when two similar harmonic transverse waves travel along a flexible string stretched tight horizontally. The planes of oscillation of these waves are perpendicular to each other, being inclined at an angle of ±45° with the vertical. Such waves do not interact with each other in a medium, yet they interact on a resonator, creating an interference pattern which is similar to light interference. As a resonator, one can use a mass suspended on a spring, which is attached to the string. The resulting interference pattern can have fringes of indefinitely large width; the result will be the same if the continuous waves in this example are replaced with traveling single wave packages.

The interference on a resonator is a trivial mechanical effect and its main advantage is the coincidence of its details with the unordinary properties of light interference. Keeping in mind the Occam's razor's claim that the «simpler explanations are, other things being equal, generally better than more complex ones» (lex parsimoniae) one can assume that light interference as a part of quantum interference is a specific case of interference on a resonator. One can easily check this assumption using the methods described in this article.

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References

[1] L. de Broglie, “Ondes et quanta”, *Comptes rendus de l'Académie des sciences* **177** (1923) 507–510.

[2] L. de Broglie, “Quanta de lumière, diffraction et interferences”, *Comptes rendus de l'Académie des sciences* **177** (1923) 548–550.

[3] L. de Broglie, “A Tentative Theory of Light Quanta”, *Philosophical Magazine* **46** (1924) 446–458.

[4] L. de Broglie, “Recherches sur la théorie des quanta”, *Annales de Physique* **3** (1925) 22–122.

[5] R.P. Feynman, R.B. Leighton, M. Sands, *The Feynman lectures on physics*, v. 3 (1963) (*atomic mechanics*).

[6] T. Hellmut, H. Walther, A.G. Zajonc, and W. Schleich, “Delayed-choice experiments in quantum interference”, *Phys. Rev. A* **35** (1925) 2532.

[7] J. Baldzuhn, E. Mohler, and W. Martienssen, “A wave-particle delayed-choice experiment with a single-photon state”, *Z. Phys. B* **77** (1989) 347.

[8] A. Tonomura, J. Endo, T. Matsuda, T. Kawasaki, and H. Ezawa, “Demonstration of single-electron buildup of an interference pattern”, *Am. J. Phys.* **57** (1989) 117.

[9] J. Summhammer, G. Badurek, H. Rauch, U. Kischko, and A. Zeilinger, “Direct observation of fermion spin superposition by neutron interferometry”, *Phys. Rev. A* **27** (1983) 2523.

[10] O. Carnal and J. Mlynek, "Young's double-slit experiment with atoms: A simple atom interferometer", *Phys. Rev. Lett.* **66** (1991) 2689.

[11] D.W. Keith, C.R. Ekstrom, Q.A. Turchette, and D.E. Pritchard, "An interferometer for atoms", *Phys. Rev. Lett.* **66** (1991) 2693.

[12] M. Arndt, O. Nairz, J. Vos-Andreae, C. Keller, G. van der Zouw, A. Zeilinger, "Wave-particle duality of C60 molecules", *Nature* **401** (1999) 680.

[13] J.A. Wheeler and W.H. Zurek, *Quantum theory and measurement*, Princeton University Press (1983) pp. 181–211.

[14] D. Bohm, "A suggested interpretation of the quantum theory in terms of 'hidden' variables", *Phys. Rev.* **85** (1952) 166–193.

[15] V. Jacques, E. Wu, F. Grosshans, F. Treussart, A. Aspect, Ph. Grangier, and J.-F. Roch, "Experimental realization of Wheeler's delayed-choice gedanken experiment", *Science* **315** (2007) 966.

[16] V. Jacques, E. Wu, F. Grosshans, F. Treussart, A. Aspect, Ph. Grangier, and J.-F. Roch, "Wheeler's delayed-choice thought experiment: Experimental realization and theoretical analysis", *Ann. Phys. Fr.* **32** (2007) 195; quant-ph/0710.2597.

[17] E.B. Aleksandrov, "Light interference", in: *Physical encyclopedia*, v. 2 [in Russian] Moscow: Soviet encyclopedia (1990) p. 166.

[18] S.I. Vavilov, *The Microstructure of light* [in Russian], Moscow: the USSR academy of sciences (1950).