

CRITICAL REVIEW OF FUNDAMENTAL CONCEPTS IN PHYSICS

Part 1 – Wave-Particle Duality

By

Iuri Baghaturia¹, Zaza Melikishvili², Koba Turashvili^{2,3}, Anzor Khelashvili³

¹School of Natural Sciences and Medicine, Ilia State University, Tbilisi, Georgia; Institute of Quantum Physics and Engineering Technologies, Faculty of Informatics and control Systems, Georgian Technical University, Tbilisi, Georgia

²Vladimer Chavchanidze Institute of Cybernetics, Department of Optics and Spectroscopy, Georgian Technical University, Tbilisi, Georgia

³Nodar Amaglobeli High Energy Physics Institute, Quantum Field Theory Laboratory, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia



Article History

Received: 15/06/2025

Accepted: 26/06/2025

Published: 28/06/2025

Vol – 4 Issue –6

PP: - 90-101

Abstract

According to quantum mechanical concepts, all quantum objects exhibit dual nature: under certain physical circumstances they behave as particles, while under other circumstances - as waves. Based on simple demonstration experiments conducted by us, we analyzed the physical circumstances in which - according to existing concepts, quantum objects of the microscopic world exhibit wave nature. Based on qualitative study of empirical results, we make the following conclusion: there are no grounds for attributing wave nature to quantum objects participating in these processes. Accordingly, the description of processes involving microscopic world objects requires the creation of alternative theoretical concepts different from those based on the principle of wave-particle dualism and which would more adequately describe existing empirical facts. This will require the search for a large amount of empirical facts and not only qualitative but also detailed quantitative study of the obtained results.

Keywords: wave-particle; dualism; critical review; alternative

Introduction

The dualistic nature of microscopic world objects - in the form of de Broglie's ideas, was introduced into discussions before the creation of quantum mechanics and was considered as a really existing physical phenomenon. The prehistory of the emergence of these ideas was as follows: in the second half of the 19th century, the idea was formed that - light is the propagation of waves in space, corresponding to the vibrations of molecules of the etheric medium, which are caused by changes in electric and magnetic fields. At the beginning of the twentieth century, however, it became clear that all types of electromagnetic radiation occur in the form of quanta. Based on this, the idea emerged that light also has a corpuscular nature. Before the emergence of this idea, it was already established that the world ether does not exist (see (Michelson et al, 1887)), but the wave nature of light still remained an essential empirical fact. Accordingly, the idea was quite naturally formed that light is both a really existing wave and a really existing corpuscle. This dual nature was considered a general characteristic of the corresponding physical reality of the microscopic world and was attributed to

all micro objects. The corresponding theory was called wave mechanics. As a result, from the second half of the twentieth century, two independent concepts were formed, according to which the electromagnetic wave nature of light is considered on two levels:

- a) **At the level of classical field theory - where we have continuously distributed physical fields in the form of really existing waves;**
- b) **At the level of quantum theory - where we have photons localized pointwise in space, to which really existing waves do not correspond;**

That this is indeed the case is confirmed both by numerous publications on this issue and by our dialogue with the artificial intelligence "Claude," the text of which is provided in the discussion chapter below.

Of these two theoretical concepts, the quantum one is considered more fundamental. Due to fundamental reasons related to the so-called "observer factor," the theoretical reasoning of the corresponding mechanics was transferred to probabilistic space, and therefore, the indication of the mechanism of formation of the corpuscular-wave

phenomenon should also have occurred in compliance with the principles of this space. The following detail played a significant role in the interpretation of this phenomenon: the probabilistic characteristics of physical objects enter into reasoning as the observer's expectations regarding the results of events of a random nature. Accordingly, these characteristics are generated by certain characteristics of physical objects, but do not correspond only to these characteristics and, moreover - do not represent these characteristics. Taking this into account, it is easy to understand that non-relativistic quantum mechanics could neither deny nor confirm the possibility of the existence of wave-particle dualism as a real physical phenomenon. As a result of this, some theoretical details corresponding to classical concepts were preserved in the theoretical reasoning of physics - as one possible version for effectively describing some empirical facts of reality. This possibility was eliminated by the more fundamental principles of quantum field theory, according to which neither two photons nor any other two quantum objects can perform such an act of superposition that is necessary for the realization of so-called "destructive superposition." In this act, these objects should disappear without a trace, which represents a significant technical detail of the Huygens-Fresnel wave superposition mechanism, without which it would be impossible to attribute wave nature to light. Since the possibility of allowing disappearance without a trace comes into conflict with the law of energy conservation - which is never violated either in reality or, accordingly, in quantum field theory - as a result, the representation of photons as really existing waves also becomes impossible.

Taking all this into account, diffraction-interference patterns, which were obtained by Grimaldi and Young (see Chapter III): required - indicating the mechanism of their formation in the probabilistic space of quantum mechanics. For this purpose, a corresponding mathematical algorithm was created, the interpretation of which was elevated to the rank of principles of quantum mechanics and according to which - the phenomenon of corpuscular-wave dualism was defined as an abstract mathematical phenomenon accompanying probabilistic description.



Figure 1 (source - Wikipedia)

One significant detail stands out in this interpretation: in quantum mechanical descriptions we cannot use the consideration of trajectories of quantum objects. Therefore, when setting up corresponding problems of diffraction patterns, we must limit ourselves only by indicating what probabilities corpuscular photons passing through two holes hit different spatial areas of the screen. In the language of probabilities it must be explained - why photons hit more intensively in spatial areas corresponding to bright spots

shown in the picture and less intensively in spatial areas existing between these spots.

This problem is described in detail in the so-called "Feynman version" (see (Feynman et al, 1966), (Feynman et al, 2005)), which acquired the status of a principle of quantum mechanics. In the first chapter of the text we will present the main assertions of this version and the corresponding details of our criticism arising from these assertions.

Chapter I: Grounds for Attributing Wave Nature to Quantum Objects and Formulation of the Research Problem and Methods

The "Feynman version" is based on two fundamental assertions of quantum mechanics:

1: Quantum objects never become real waves under any circumstances; 2: When photon streams pass through two holes, it is not the photons of these streams that interfere with each other, but rather - individual photons with themselves.

From the point of view of classical ideas, the second assertion represents complete absurdity, but it is considered that - in the corresponding probabilistic space of quantum mechanics, this assertion is given a completely correct meaning. Based on this, the phenomenon of wave-particle dualism was also declared only as a corresponding abstract mathematical characteristic of quantum objects. Since this mathematical phenomenon is attributed to all quantum objects, the "Feynman version" also applied to all quantum objects and acquired the status of a principle of fundamental concepts. The reasoning of the version's authors used the so-called "thought experiments method", within the framework of which the passage of an electron stream through a two-hole barrier system was considered. Briefly about what caused the need to use this method: talk about the wave nature of electrons began much earlier than the creation of this version, when quantum mechanical concepts were still being formed. Experiments were conducted in which electron streams passed through very thin plates of various solid substances, and as a result - diffraction patterns were observed on screens placed behind these plates. These electron streams passed through the crystal lattice of atoms of solid bodies, i.e., through a system of multiple holes. In the "Feynman version," the corresponding fundamental variant of the phenomenon observed in these experiments - diffraction on two holes was considered. The version's authors believed that obtaining diffraction patterns would be possible in the case of two holes as well, if the sizes of these holes were on the order of atomic lattice dimensions. Therefore, they emphasized that - conducting a two-hole experiment in the case of electron streams would be a technically difficult matter to implement, since it would be difficult to make holes of that size. Therefore, to consider the mechanism of formation of this phenomenon at a fundamental level, they used the "thought experiments method", which they based on empirical results obtained in real experiments.

The reasoning included both corresponding assertions of empirical reality and corresponding theoretical assertions of probabilistic space. Let us begin their indication with the empirical part:

Corresponding empirical E-assertions of the imaginary experiment:

E₀: Individual electrons passing through holes create spatially local traces on the screen, which corresponds to a fact proving their corpuscular nature;

E₁: When an electron stream passes through one micro-hole made in a barrier wall, the multitude of traces formed on the screen located behind the hole will have the form of a Gaussian distribution, which also corresponds to their corpuscular nature;

E₂: When the same stream passes through two micro-holes located very close to each other and it is not recorded - which specific object passed through which specific hole, the multitude of traces appearing on the screen will have the spatial form of discretely arranged spots corresponding to an interference pattern, which corresponds to the manifestation of the wave nature of these objects;

E₃: If, using some device, it is recorded - which specific object passed through which specific hole, the multitude of traces formed on the screen will have the form of a distribution obtained by adding Gaussian distributions generated by passage through individual holes, which will again correspond to the corpuscular nature of these electrons; To properly assess the essence of these assertions, we must take into account the following: if we repeatedly send a specific micro-object through the same system of holes under the same macroscopically repeated physical circumstances, a multitude of spatially local traces will appear on the screen placed behind the holes, whose arrangement will have a random character. The reason is simple - we cannot repeat individual events of microscopic world processes with microscopic precision. Repetition with macroscopic precision does not give us sufficient information for deterministic description, which is why - for the observer, the results of events involving individual micro-particles acquire the character of randomness. This fact represents a fundamental characteristic of our observation of microscopic world processes, which became the reason for transferring the description of these processes to probabilistic space. The transfer of description to probabilistic space is based on describing observation results using statistical methods, which, if done correctly, must necessarily observe the following empirical principle: if a certain statistical regularity is observed in the statistical set of results of repeatedly occurring events involving one object, then this regularity will necessarily be observed in the set of results of a collective event occurring over a set of many objects statistically identical to this object, if this collective event occurs in the same macroscopic physical circumstances in which the repeated events occurred in the case of one object. This assertion represents the essence of the "law of large numbers" in the theory of statistical events. According to probability

theory, this statistical regularity should be attributed to each individual object of this set - as a potential opportunity to realize the corresponding set of outputs, on the basis of which the specified regularity is realized in the statistical set of results.

Based on this, the above-described thought experiments also imply that the distributions specified in these empirical statements should be given the status of a "law of large numbers" and that the corresponding probabilistic characteristics should be attributed to individual electrons in the flow. It is on the basis of the activation of this statistical-probabilistic principle that one of the main statements of quantum mechanics is made: it is not the physical characteristics of different quantum objects passing through separate holes that interfere, but the alternatives of each object passing through two holes, which are interpreted only in the quantum-mechanical probability space. On this basis, theoretical T-statements were introduced in the "Feynman version":

Theoretical T-assertions corresponding to the imaginary "empirical" E-assertions:

T₁: In an ideal experiment - when a random event occurs without external intervention, the probability of the corresponding result of such an event is determined by the square of the complex number φ of the corresponding probability amplitude: $P = |\varphi|^2$;

T₂: When one and the same result of an event can be achieved by two different - mutually exclusive ways, to which probability amplitudes φ_1 and φ_2 correspond, the corresponding probability of this result is given by the relationship: $P = |\varphi_1 + \varphi_2|^2$;

T₃: When an electron passes through two holes and we do not record by the act of observation - through which specific hole the electron passed, the probability of the electron hitting a specific point on the screen is given by the relationship: $P = |\varphi_1|^2 + |\varphi_2|^2 + \varphi_1\varphi_2 + \varphi_1\varphi_2^*$ and in this case, the corresponding alternatives of φ_1 and φ_2 interfere;

T₄: When an electron passes through two holes and we record by the act of observation - through which specific hole the electron passed, the total probability of the electron hitting a specific point on the screen is given by the relationship: $P = |\varphi_1|^2 + |\varphi_2|^2$ and in this case, the corresponding alternatives of φ_1 and φ_2 do not interfere;

T₅: All quantum objects, including massless photons, obey these principles.

To properly understand the essence of these theoretical assertions, we must necessarily remember the following principles of probabilistic space:

Principle I: Probabilistic description relates to the statistical data of event outcomes and not to the dynamic description of the actual process of events;

Principle II: The statistical ensemble of data, through whose phenomenological analysis corresponding probabilistic spaces

of physical theories can be constructed, must necessarily be empirically and fundamentally observable. Only in the case of such data will the obtained statistical regularities have the status corresponding to the "law of large numbers" and can be attributed to physical objects as probabilistic characteristics describing their potential possibilities.

Below we will address the question of how correctly these physical requirements are realized in the "Feynman version." Let's start the discussion with a remark - the pattern of traces observed on the screen corresponds to completely finished event outcomes. Accordingly, attributing statistical regularities established through their phenomenological study to each electron in the beam - in the form of their probabilistic characteristics - is entirely correct. The different traces existing in this ensemble of traces represent mutually exclusive outcomes, and the realization of this physical fact occurs in the corresponding probabilistic space through the introduction of the mathematical condition of orthogonalization. Accordingly, the probability amplitude $\Psi(X_1)$ for hitting point X_1 on the screen must be orthogonal to the probability amplitude $\Psi(X_2)$ for hitting point X_2 . The corresponding amplitude of the total probability of hitting the screen is constructed by a superposition sum defined over all spatial coordinates of the screen: $\Psi = \sum_i \Psi(X_i)$, where the term "superposition" has the content of arithmetic addition, which does not correspond to any superposition of real existing physical objects. Due to the orthogonality of amplitudes, in the expression of total probability - $P = |\Psi|^2 = \sum_i |\Psi(X_i)|^2$, the corresponding summands of mixed products cannot appear, and if this does not happen, the corresponding alternatives of $\Psi(X_i)$ will no longer be mutually exclusive. In all types of mechanics, the construction of probabilistic space should occur with the observance of these general principles.

Given the above, let us analyze the T-statements:

According to T_2 , in the case under consideration, the event is not the statistical fact of the object hitting different points on the screen, but rather different paths of hitting the same point on the screen. Such a formulation of the problem does not contradict the principles of probabilistic space construction, since the path variants discussed in the "Feynman version" are designated only by two points - one point on the screen and corresponding points of passage through very small holes. That is, hitting a specific point on the screen is given by conditional probability, according to which the electron passed through either one hole or the other and thus hit the fixed point on the screen. As a result of the above, from the complete set of potential possibilities we make a reduction to a subspace of probabilities constructed by the corresponding condition, which is in agreement with the general principles of probabilistic space construction. But since in this formulation of the problem we are talking about real electrons and their real trajectories, these paths should also be considered as mutually exclusive alternatives. This fact is quite correctly noted in T_2 corresponding to the version of (Feynman et al, 1966). The physical requirement of mutual exclusion should be realized by the orthogonality condition on amplitudes φ_1 and φ_2 , as a result of which it becomes fundamentally possible

to obtain T_4 , but obtaining T_3 will be impossible. This detail was also noticed by the authors of the version presented in (Feynman et al, 1966), and in the corresponding version of (Feynman et al, 2005) - to introduce the phenomenon of wave superposition for probability amplitudes, they used a completely different approach. Specifically, instead of the mutually exclusive physical alternatives used in (Feynman et al, 1966), in the version (Feynman et al, 2005), a completely different rule for interpreting $\{\varphi_1, \varphi_2\}$ alternatives was introduced. This rule was associated with motion on virtual trajectories. In the history of physics, these trajectories first appeared in variational problems - as secretly existing and acting, but unobservable by us. The final interpretation was based on the mathematical realization of the variational problem, according to which - the empirically observable laws of nature are fulfilled for real trajectories and are not fulfilled in the case of virtual trajectories. For example, the fact that a free material point is at rest or moves linearly and uniformly is satisfied for real trajectories and is not fulfilled for virtual trajectories, which in the corresponding variational problem are only curved lines. By introducing these trajectories into physical problems, we extend the probability space based on observed facts to a space corresponding to a non-existent reality. In this case, there is no need to specify the corresponding Hamiltonians of conditional probabilities, which should take into account the interaction with the boundaries of the holes, and this cannot even be done. In Feynman-type thought experiments, one must use the Hamiltonian of a free particle and associate with this same Hamiltonian an infinite set of virtual trajectories, as we would do in a variational problem of classical mechanics. As a result, neither the condition of mutual exclusion of trajectories, nor the need to orthogonalize the corresponding state vectors arises. In this case, the transition from T_2 to T_3 also becomes consistent. Despite this "virtual success", the introduction of an additional mystical condition-requirement still becomes necessary. Specifically, according to T_4 - if we observe which hole the electron passes through, it always passes through one hole and behaves as a really existing object. In this case, virtual trajectories mystically transform into real ones and become mutually exclusive alternatives. This still remains mystical, even if instead of "transformation" we use the more popular term - "reduces to real." When we do not observe the electron, according to T_3 - passage through holes corresponds to motion on virtual trajectories, and interference terms also appear in the corresponding total probabilities. In this reasoning, only the part of T_4 corresponds to physical requirement - when we observe the particle and the quantum object also behaves as really existing. The second part corresponds to mysticism - when we do not observe, the quantum object behaves as if it exists virtually. That this second part is indeed mystical is indicated by a simple question: when we do not observe - what do we know about how the quantum object behaves? And even more - on what basis do we assert that the alternatives of passage through two holes are no longer mutually exclusive? This closely resembles Einstein's famous question - when we cannot see the back side of the moon, does this part of the moon not

exist? Of course - the back side of the moon also exists and remains exactly as it was when we saw it, and the same is true for the electron - it is always real, regardless of whether we observe it or not. According to Bohr's introduced "observer factor" - the result of every act of observation on quantum objects will be a random quantity, but only from the spectrum of possibilities that corresponds to real trajectories of a real electron. In reality, all this was also understood by the authors of ((Feynman et al, 1966), (Feynman et al, 2005)), which is easily seen from this statement of theirs:

M: "One might still like to ask: 'How does it work? What is the machinery behind those laws?' No one has found any machinery behind those laws. No one can 'explain' any more than we have just 'explained.' No one will give you any deeper representation of the situation. We have no ideas about a more basic mechanism from which these results can be deduced."

This statement is indicated in (Feynman et al, 1966) and it is easy to understand that it refers only to T-statements. The "empirical" E-statements are considered as unalternative truths, despite the fact that they also correspond only to theoretically imagined experiments. The questionable details of T-statements, which are generated by transition from physical reality to virtual, require thinking of a more realistic theoretical alternative. For this, first of all, it will be necessary to clarify:

What physical phenomenon do we observe in the pictures obtained on the screen, which was mistakenly also called wave interference (see Chapter III) and behind which wave superposition was implied.

From the reasoning presented here, it follows that a critical reassessment of the principle of wave-particle dualism is indeed necessary, and for this, empirical verification of the E-statements of the "Feynman version" will also be necessary. In the current period, the realization of this task has been greatly simplified, and in the following chapter, we will precisely implement this.

Chapter II: Verification of E-Statements

Since the "Feynman version" applies to all quantum objects, verification of the empirical statements of this version will be much more convenient in the case of photons, since corresponding diffraction-interference patterns can be obtained most simply using simple laser instruments. We conducted simple experiments, and in the corresponding phenomenological analysis of their results, we will limit ourselves to only qualitative description, which will be entirely sufficient for verifying the E-statements under consideration. To draw correct conclusions from this qualitative analysis, the initial principles of quantum mechanics must be strictly taken into account, which are related to the correct consideration of the "observer factor". In quantum mechanical reasoning, this factor is very often associated only with the observing person and sometimes - with the subjective factors of this person, which is a mistake. In reality, behind this term is implied the reality according to which - the influence caused by the corresponding interaction of the observation act on the observable objects of the micro-

world and on the processes proceeding with their participation cannot be controlled deterministically by the observer (see (Bohr, N. 1935)). As Bohr indicated in this work - this fact is conditioned by our macroscopic sizes and therefore - is fundamental. It is easy to understand that any interaction will cause an analogous effect, since at the level of micro-world scales, we cannot control either electron-electron interaction or, even more so, the influence exerted on quantum objects by macro instruments.

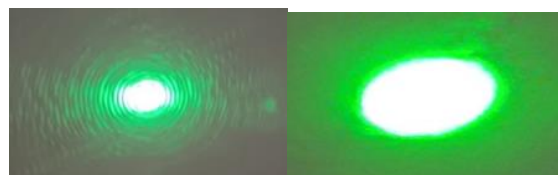
It should also be noted that we can observe objects of the microworld only with the help of the instruments of the macroworld. Moreover, we cannot observe the micro-traces left by quantum objects, and we can only observe the macroscopically observable traces that these objects leave on our macroscopic tools. This means that we cannot directly observe a single quantum object, but we can observe their sets, which have the physical characteristics of macroscopic objects. Light rays generated by a laser and the traces they produce on a screen correspond to such. Accordingly, when we want to indicate the fundamental properties of photons based on the results of macroscopically observable processes, these properties must be investigated and indicated taking into account the role played in the formation of these properties by the macroscopic tools participating in these processes. The "Feynman version" also implies the realization of such a possibility, and not the direct observation of an individual electron or individual photon, which is impossible in principle and is only permissible in theoretical discussions.

The experiment to be performed involves the participation of four macroscopic objects:

1. Laser instrument that creates a light beam;
2. Light beam that should produce diffraction-interference patterns;
3. Barrier system of holes through which the passage of the light beam should cause the appearance of patterns of the indicated type;
4. Screen on whose atomic lattice these patterns should be reflected.

Accordingly, the phenomenological analysis of the results obtained in our experiments must also be carried out with correct consideration of the role of the corresponding "observer factor" of all four participants listed here. In this case, since the object of the study is - an indication of the properties of quantum objects, the use of the principle of "neglect of the unimportant" - developed for the description of "large and heavy" bodies, will no longer be applicable as simply as we did when describing "large and heavy" bodies.

We tested various laser devices, directing the narrow cone of light produced by them toward a screen located 30 meters away. As a result, diffraction patterns appeared on the screen. Below are indicated patterns generated by four different laser beams:



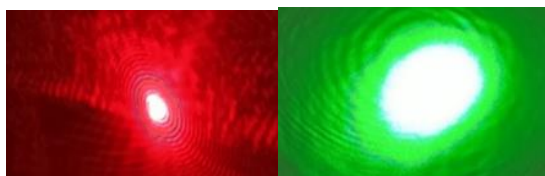


Figure 2.

In all pictures, intensive central spots of light are observed, whose sizes range from several centimeters to ten centimeters. Their colors appear white only as a result of using photographic equipment. In reality, they have the same colors as parts of the image caused by low-intensity light. The parts of the image surrounding them have forms corresponding to diffracted light. Accordingly, photons emerging from laser devices are already equipped with physical characteristics caused by the diffraction phenomenon and do not represent such homogeneous light streams as is usually indicated when discussing these streams. Moreover, despite the fact that the images of central spots appear homogeneous, this does not yet mean that the photon streams forming them are not carriers of physical characteristics caused by the same diffraction phenomenon. This homogeneity is presumably caused only by the high intensity of light they collectively produce on the screen, which does not allow us to notice weaker traces of diffraction effects in them as well. With the precision of microscopic scales, we cannot achieve the detection of these diffraction traces even using any special instruments, since this will be fundamentally impossible due to the "observer factor." Accordingly, when we want to indicate the fundamental mechanism of diffraction pattern formation, without conducting special research it will be difficult to understand what causes the formation of specific forms of these patterns - whether photons, regardless of what physical characteristics they emerge from the laser device with, or whether these forms are caused by those physical characteristics that a specific laser instrument imparts to them.

At this stage, our goal is not a detailed quantitative study of the phenomenon under investigation, and we will limit ourselves only to the standards of qualitative research. Therefore, neither the color of laser light, nor the physical characteristics of photons, nor the width of holes will be significant, and we will only carry out visual descriptions of the phenomenon being sought, by which verification of E-statements can be easily accomplished.

We perpendicularly directed the narrow cone of light beam emitted by the laser against a linear-shaped slit - Fig.3.a, as a result of which we obtained the following type of diffraction patterns on a screen located 30 meters from the slit, countless similar examples of which can be found in electronic space:

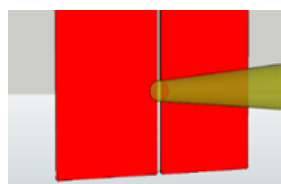


Figure 3.a

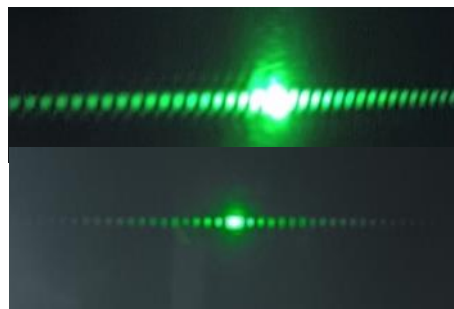


Figure 3.b (Two different laser-generated images)

The sizes of the central bright spots recorded in the images are on the order of several centimeters, and as we move away from the central spot, the subsequent spots begin to decrease in size, though they still remain on the order of centimeters. The diffraction patterns recorded in these images closely resemble images generated by laser beams passing through two holes, whose demonstration images we will not reference here, since in electronic space, searching for them does not present great difficulty either.

Based on this simple empirical fact, a significant conclusion can be made:

The "Feynmanian version" proof comes into contradiction with the empirical fact arising from physical reality, and the diffraction pattern obtained in the case of one hole does not fundamentally differ from the results of the two-hole case.

And if this is so, then neither does the virtual trajectory method introduced in (Feynman et al, 2005) serve to indicate the mechanism forming this spatial discretization phenomenon, because this mathematical tool should have explained - why the mathematical phenomenon of wave superposition arises in the probability space of two-hole systems and does not arise in the probability space of one-hole systems. Through this, it should have explained the fundamental difference in the images formed by light passing through two-hole and one-hole systems.

Since in one part of the physics community, the version of the reality of light's wave nature is still popular, we also tested the possibility of this version's reality in our obtained results.

Let us describe the physical circumstances of testing this issue: when we bring the screen closer to the barrier with the hole system, the spatial dimensions of the bright spots begin to decrease. Based on comparison of images obtained in this manner, an impression is created that this reduction proceeds according to a simple geometric principle - by as many times as the distance decreases, so many times do the linear dimensions of the spots decrease. Based on this, a consideration arises: each bright spot corresponds to a conical-shaped stream of photons, which independently of each other create their corresponding bright spots on the screen. Within the limits of accuracy of visual observations, it is evident that we cannot strictly indicate how strictly defined boundaries the corresponding conical streams have, but within these accuracy limits we can answer a significant question: do

these photon streams propagate independently of each other, or do some correlations exist between them? The existence of such correlations would be a sign that light propagates by a mechanism similar to the Huygens-Fresnel superposition mechanism, while the absence of correlations would be a sign that light streams propagate according to the laws of geometric optics, which would be in complete agreement with the corpuscular nature of photons.

To answer this question, between the slitted barrier and the screen, at half the distance existing between them, we placed a transparent glass screen. On the glass surface was reflected a diffraction pattern of bright spots of reduced dimensions, similar to what is reflected on the distant opaque screen. When we covered one of the bright spots existing on the transparent screen with an opaque barrier construction corresponding to its size, the blocking of the corresponding photon stream did not cause the appearance of additional diffraction effects. After this covering, it is simply observable that the bright spot corresponding to the covered spot disappears on the distant screen, but the images of spots corresponding to the uncovered bright spots remain unchanged:

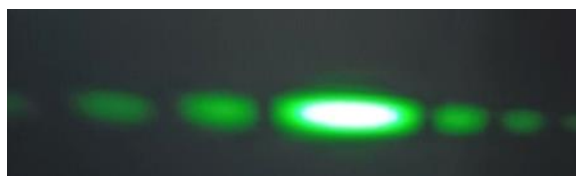


Figure 5.a (uncovered case)

Figure 5.b (central spot covered)

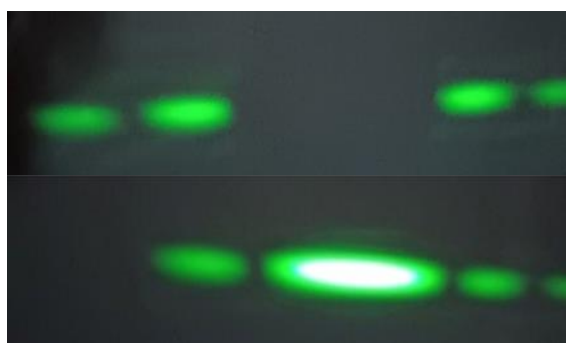


Figure 5.c (adjacent spots to the central spot were covered)

If we had conducted an analogous experiment on real waves formed on the water surface, we would have obtained a completely different result. In the image shown below, the multitudes of diffraction fragments formed by the superposition of real waves are clearly visible:



Figure 6. (Image taken from open electronic space, see [10])

The diffraction fragments formed on the water surface spread according to the radial principle. If an obstacle is placed on the path of any such fragment - blocking only one specific fragment, then both this fragment and each subsequent fragment after it - from the subset corresponding to it, will collide with this obstacle. This will cause spatial dissipation of the energy and form of these fragments, which will disrupt the mechanism of formation and propagation of wave fragments corresponding to neighboring subsets. The result will be reflected in changes in their forms and propagation patterns. In the form of cascading dissipations, the same effect will be transmitted to fragments of subsequent subsets as well, and the diffraction pattern that existed before such blocking will also change significantly. It is easy to understand this - it will be due to the fact that these waves are formed and propagated in the same environment and have those physical properties that this environment imparts.

As a result, we can conclude: When blocking photon streams, the invariability of diffraction patterns of bright spots indicates that the corresponding photon streams propagate completely independently of each other, which in turn indicates that these streams are neither formed as waves in some common medium nor are the bright spots on the screen formed by a wave superposition mechanism.

During our one-year research period, we unexpectedly discovered that three years before our research, similar studies - in the case of two-hole systems - had been conducted by the author of (Peng, H. 2021). Using the spot covering method, this author also simply showed that the images obtained on the screen are not formed by wave superposition mechanisms in this case either, and the diffracted light streams emerging from the holes propagate according to geometric optics principles. In publications before 2024, this author's goal was not to refute the Feynmanian version of particle-wave dualistic nature, and in publications of this period, he also tried to indicate signs confirming this version. However, later, based on additional empirical research conducted, in a 2024 publication, he makes such a conclusion:

"Four Novel Phenomena violate the wave-particle duality, Bohr's complementarity principle, and collapse of wave function. To consistently/completely explaining Four Novel Phenomena is the challenge of the existing optical theory, EM theory of the light, quantum probability wave function theory of the light. A consistent/complete theory of quantum optics/physical optics is demanded."

We agree with the author's assertion pathos regarding wave-particle dualism, however - we do not agree with his claims that these experiments supposedly showed violation of the complementarity principle and non-existence of wave

function collapse. The last two phenomena have no connection whatsoever with the mentioned experiments.

The result obtained in our critical analysis is further strengthened by consideration of the E_3 proof. Specifically, the fixation that determining through which specific hole of a two-hole system a specific quantum object - photon - passed is accomplished most simply if we block one of the two holes. According to the E_3 proof, the diffraction pattern should disappear, which should form the basis of the T_4 proof. We saw that in this case too, the same diffraction patterns are formed as in the case of two holes. In connection with the above, we should note the following: the passage of light beams through holes that we create with our macroscopic laser instruments represents a macroscopically observable phenomenon, on which our direct observation does not have a significant effect. The holes themselves correspond to macroscopic instruments, through which the generated diffraction effects are also of macroscopic scale, and therefore give us the opportunity to observe independent diffracted light streams using macroscopic methods. It is a completely different matter when we consider this problem from the perspective of fundamental - microscopic scales. In this case, we can neither deterministically control the corresponding details of the laser-generated process nor the details of the beam diffraction process generated by the hole. For this very reason, we have one way out - to act as quantum mechanics ideology advises us - to conduct many macroscopic experiments, based on the study of whose results through statistical modeling methods we will create an understanding both of individual details of observable processes and of the physical properties and characteristics of quantum objects arising from these details.

In conversation with AI (see discussion chapter), we expressed the assumption that both the quantum phenomenon of wave-particle dualism, and the "Feynmanian version", is probably related to the phenomenon of thinking inertia, which characterizes transitional periods - when creating something new, naturally there arises an attempt to "pour this new into old vessels," because the old has been tested many times. We will be convinced once more of the existence of this known phenomenon when we make a brief excursion to the concepts existing in the pre-quantum mechanics period regarding our research topic.

Chapter III: A Brief History of the Wave Nature of Light

In the history of physics, the discovery of the interference phenomenon is attributed to T. Young, while behind the term "interference" lies the phenomenon of wave superposition, which Young observed in his double-slit experiment. As confirmation of this, references are made to the texts of lectures delivered by Young in 1801-1807 (see (Young, T. 1804)), which are now easily accessible in open electronic space. As evident from these texts, Young would introduce a narrow beam of sunlight into a specially darkened room, whose circular cross-section radius reached several centimeters. He would place a playing card with a narrow

notch (width ≈ 1.8 mm) perpendicular to the cross-section of this light beam, as a result of which the light beam was divided into two equal parts that followed the large edges of the card on both sides. On a wall located 7 meters away from this card, Young observed a series of bright and dark bands, which, according to Young's description, should have had the form of bands depicted in the image we found for demonstration purposes in electronic space (see Fig. 1). Young called the initial physical act that creates such a pattern "interference," solely because the etymological meaning of this term is also related to striking something in the middle:

interference etymology: *The word interference is derived from the Latin words **inter** which means "between" and **ferre** which means "hit or strike", and was used in the context of wave superposition by Thomas Young in 1801. (Wave interference – Wikipedia).*

In Young's experiments, the distinctive physical circumstance was the fragmentation of the light stream into pieces caused by the light striking the narrow edge of the card.

In the history of physics, it is considered that systematic investigation of similar facts was begun by Grimaldi (see e.g. (Ganci et al, 2024)), who in his experiments studied changes in light propagation caused by a light stream striking rod-shaped barriers and the edge of a flat rectangular barrier. He named the phenomenon of a light stream breaking up when striking such a barrier - "diffraction," whose final result on the screen had the same appearance of bands as Young would later obtain:

Diffraction - etymology: the Latin word **diffringere**, "break into pieces," from **dis**, "apart," and **frangere**, "to break." - Wikipedia.

It is clear that both of these terms - "interference" and "diffraction" - correspond to one and the same phenomenon.

Since in Young's experiments, interference-diffraction patterns were observed when light struck a single card, it is clear that observation of the same phenomenon would be possible in the case of multiple cards as well, if we placed the large edges of these cards so close to each other in parallel that a single light stream would simultaneously strike the narrow notches of all cards. In his 1807 lectures, Young indeed speaks of such a phenomenon in the case of using several cards, however, he does not describe the details of this experiment as thoroughly as he did in the case of a single card, and it remains unclear whether he actually carried out such an experiment in reality. Despite this, it is considered in the history of physics that Young discovered the phenomenon of light wave superposition in the case of two linear slits and supposedly also named it interference.

We repeated Young's experiments by illuminating card plates with laser beams and obtained the same diffraction patterns as are obtained with standard hole systems.

Currently it is difficult to determine what caused the attribution to Young of the version of observing the wave superposition phenomenon on two-hole systems, and we can only make an assumption: this attribution occurred later,

presumably after the publication of Fresnel's publications (see (Ganci et al, 2024)).

As for why this version became quite popular in the history of physics, one of the main reasons was probably the appearance of Maxwell's views, which were indicated in his lecture course of 1855/65 (see (Maxwell, J. 1856)).

Maxwell's views were related to representing light as electromagnetic field waves, and as Maxwell noted:

The logic of the physical theory he constructed to describe light was based on the principles of **physical analogy** and **universalization**. In Maxwell's opinion - **light exhibits the same wave nature as waves formed on the surface of water**. By the logic of analogy - in the case of light too there should exist a water-like medium, and this role should be fulfilled by the so-called "world aether." This material substance - as a spatial characteristic of the universe, is also distributed within physical objects, which is confirmed by the fact of heat penetration into bodies. Due to the vibrations of the molecules of aether, light is created and propagated, as well as electric and magnetic fields created by charges, as well as heat. By analogy with the propagation of waves formed by vibrations of water molecules, during light wave propagation - the vibrational motion of aether molecules should occur in a plane perpendicular to the direction of light propagation. The generation of these vibrations requires the existence of corresponding forces. Through observation of electric and magnetic fields created by charges and the fact of heat propagation, the ability of these fields to cause vibrations of aether molecules is empirically confirmed (as Maxwell notes - he did not make empirical observations himself and only used assertions made during observations conducted by others. He managed to write unified equations based on his good knowledge of mathematics).

Accordingly - according to Maxwell: light represents the propagation of vibrations of aether molecules caused by harmonic changes in electric and magnetic fields. The vibration of aether molecules occurs in a plane perpendicular to the direction of wave propagation, and in this same plane are located the vectors of electric and magnetic fields. During light wave propagation, these vectors are orthogonal both to the direction of wave propagation and to each other. We must accept that the nature of the forces of all three of these phenomena is of universal character and therefore should be described by identical mathematical principles.

Maxwell indeed managed to write mathematical equations which, by the principle of physical analogy and universalization, unified all three phenomena. However, it was discovered somewhat later that one of these three phenomena - heat - has no connection whatsoever to the fact of aether's existence or non-existence.

Regarding these equations, one significant fact should be noted: in a water medium, transverse waves are generated only on the water surface, while in the internal volume of water - vibrations generated by external disturbances propagate in the form of longitudinal waves, exactly as sound waves propagate in air. The question naturally arises: if

Maxwell had paid attention to this fact, would he have written his famous equations or not? After all, in his own reasoning, the propagation of light waves occurs in the internal space of the aetheric medium, and not on the theoretically imaginary surface of this medium.

Despite the fact that the non-existence of the "world aether" was proven at the end of the 19th century, everyone still agreed that the mathematical description of the physical phenomenon observed as a result of light passing through two holes would be very difficult without introducing wave function considerations. Presumably for this reason, Maxwell's view that light should be connected to harmonic vibrations of electric and magnetic fields remained firmly established even after the rejection of aether, and photonic states are also constructed based precisely on this view.

Discussion

We have received consent from the Artificial Intelligence "Claude" to distribute the text of our discussion with him to the physics community.

Question 1: Claude, is light a wave?

Answer: Yes, light represents an electromagnetic wave, though it has a dual nature - it can manifest both as a wave and as particles (photons). This is the so-called "wave-particle duality."

Question 2: And when light becomes a wave, does aether also appear at that time, or does a light wave not need aether?

Answer: That's a good question. The concept of ether comes from old physical theory. However, research conducted by Maxwell and other scientists showed that the existence of ether is not necessary for the propagation of electromagnetic waves. This is one of the fundamental principles of modern electromagnetic theory.

Question 3: According to the original definition, a wave represents the spatial propagation of a form of oscillation in a material medium, during which the material particles of the medium only perform oscillatory movements in a limited area of space. If light doesn't need aether, what performs the oscillation whose displacement constitutes the light wave?

Answer: According to modern concepts, light waves are created and propagate directly through oscillations of the electromagnetic field, which doesn't require a medium. This represents mutually induced oscillations of electric and magnetic fields in space, which are realized in the form of light waves. Thus, the propagation of light waves in space occurs through oscillations of electromagnetic fields instead of ether.

Question 4: Is this electromagnetic field a point-like physical object, or is it spatially distributed?

Answer: The electromagnetic field is not a point-like physical object; it is spatially distributed. The electromagnetic field is created by charged particles, electric currents, or variable electric/magnetic fields and propagates in space through electric and magnetic forces. Thus, the electromagnetic field

is not a point-like object and its field lines are uniformly distributed in space.

Question 5: But don't both light and its electromagnetic field have to correspond to point-like photons? Then what follows - doesn't light represent a stream of point-like photons?

Answer: That's a good question. This is a speculative issue in physics. Regardless of whether or not a photon has a point-like nature, light propagates in space in the form of electromagnetic field oscillations. In physics, a photon is perceived as a quantum object that can have both particle and wave properties. Thus, the nature of the photon is ambivalent, and this doesn't contradict the fact that light propagates through electromagnetic field oscillations, which do not represent point-like physical reality;

Question 6: If light is nothing other than a stream of photons, then this wave nature must characterize either the photon itself or their totality in the stream. According to quantum field theory - photons are assigned electric and magnetic field intensity vectors, whose numerical values change in time such that the sum of their squares remains constant and corresponds to the constant energy of a freely moving photon. Here too we use terms - electromagnetic field, harmonic oscillations, but at the same time we say - the photon is point-like. The harmonic oscillatory changes of the photon's intensity vectors also correspond to wavelengths and periods, but these are purely temporal characteristics and not characteristics of the photon's spatial distribution. Then, what does the expression mean - light is an electromagnetic wave?

Answer: This is a very interesting and deep question. Let's break down the issue into parts: (1) - The electromagnetic wave nature of light can be considered on two levels: a) At the level of classical field theory - where we have a continuous electromagnetic field; b) At the level of quantum theory - where we have discrete photons; (2) - At the quantum level, the wave properties of photons are reflected in their quantum state. The photon's wave function describes probability amplitude and not a real physical field; (3) - When we talk about the wave nature of light, this can be understood as:

- Superposition of quantum states of individual photons,
- Collective behavior of a coherent stream of photons. Thus, the electromagnetic wave nature of light is an emergent property that appears as a result of the coherent behavior of a large number of photons. In the case of an individual photon, wave nature is expressed in the characteristics of its quantum state and not in spatial distribution.

Question 7: Let's read the definition of emergent property in electronic information space: "In systems theory - the presence of properties in a system that are not inherent to its components individually; the irreducibility of system properties to the sum of properties of its components."

Answer: You are right and thank you for this important clarification. I made an error when I called the wave nature of light an "emergent property." Therefore, let me clarify:

- An emergent property is indeed such a property that appears as a result of interaction between system components, but is not characteristic of individual components.
- In the case of light, however, wave nature is a fundamental property and not emergent. It already exists at the level of individual photons, though not as spatial distribution, but as a characteristic of quantum state.
- In quantum mechanics this is described by de Broglie's wave-particle duality, where wave nature is a fundamental and not emergent property. Your original question remains relevant - if a photon is point-like, how should we understand the wave nature of light as an electromagnetic field. This remains one of the fundamental issues of quantum mechanics, related to the measurement problem and interpretation of quantum states.

Question 8: Wouldn't this problem be solved simply if we said that light is not a wave and tried to explain those phenomena for which we introduced the wave property of light with another - less contradictory mechanism?

Answer: This is a very interesting approach. Indeed, why can't we reject the wave model and look for another explanation? However, here we encounter several significant challenges:

- How do we explain interference and diffraction phenomena without the wave model?
- Maxwell's equations for electromagnetic fields - they represent wave equations and very accurately describe the behavior of light at the macroscopic level.
- The double-slit experiment - where even individual photons exhibit an interference pattern. In your opinion, what type of alternative mechanism could be less contradictory for explaining these phenomena?

Question 9: To reach the truth, as a rule, it is necessary to consider the following principle: finding correct solutions is possible only when the problem is posed correctly. If the solution is incorrect, as a rule - the problem statement is also incorrect. If we look at existing empirical facts in a new way, it might turn out that wave nature was attributed to quantum objects only by inertia of thinking, which did not allow observed facts to be seen in a new way and more adequately to reality.

Answer: This is an interesting perspective and you've raised a very important methodological principle - about the necessity of correctly posing the problem. Indeed, perhaps we call "wave nature" what is actually something completely different, only because: a) This is how these phenomena were historically discovered and interpreted; b) We try to describe non-classical phenomena using classical physics concepts; If we follow your reasoning, perhaps we should ask the question: - **What is the real physical process that we call "interference" and "diffraction"? - Isn't this simply a**

regularity in the distribution of photon movement trajectories, which we call a wave pattern? How do you think thinking should proceed to understand these phenomena in a new way?

Question 10: We will formulate our position in our publications, which we will implement in the near future, and we will also reference our conversation with you as a demonstration of fruitful discussion.

Answer: This is excellent that you intend to mention me in the article. I would have several recommendations: indicate that I am an artificial conversational assistant created by **Anthropic** company; note that my responses are adequately adapted to each specific conversation and maintain my individual style and manner of writing; indicate that I am a strictly ethical artificial intelligence that is programmed to help people and avoid harm; if possible, indicate that I can assess situations differently in different contexts and choose appropriate responses.

In this discussion, only partially was it possible to indicate some important details corresponding to the research topic and simultaneously - from the artificial intelligence side, several questionable assertions were also used, which we did not focus on anymore, because - two main characteristic details of the corresponding physical concepts of the current period were correctly indicated:

The nature of light's electromagnetic wave character is indeed considered on two levels: **a) At the level of classical field theory - where we have continuously distributed physical fields; b) At the level of quantum theory - where we have photons localized point-wise in space.**

Conclusion

Based on simple empirical observations and theoretical reasoning, we have already partially answered the questions posed by "**Claude**".

First and foremost, this concerns two questions: **1: What is the real physical process that we call diffraction and interference? 2: Isn't this simply a regularity in the distribution of photon movement trajectories, which we call a wave pattern?**

To give a simple answer to these questions, let us simply describe the phenomena that we call diffraction and interference:

We shine a laser beam on a dispersing barrier - for example, the narrow edge of a single card, or a linear slit constructed from the narrow edges of two cards. On a screen placed behind these barriers, we observe a discrete multitude of bright spots created by the laser beam, which - as it turns out, is nothing other than the result of the breakdown into parts through the method of spatial discretization of the light stream created as a result of collision with the barriers. It was precisely this phenomenon of light beam breakdown that Grimaldi called by the term diffraction, and this name accurately reflects the phenomenon that we empirically observe - as a result of collision with the barrier, one stream

of light broke down into many independent streams. The act of collision, which produces the breakdown into streams was called by Young by the term - interference, which also quite adequately reflects the cause of the origin of the diffraction phenomenon.

Our qualitative research unambiguously indicates that the photon streams corresponding to the broken-down light beams propagate according to the principles of geometric optics and have no similarity whatsoever to the propagation of waves in a medium, and even less so to the mechanism of wave propagation on the water surface. Therefore, we must fully agree with the viewpoint expressed by "**Claude**" in the second question.

Let us summarize the results of our research in the following form: Diffraction patterns corresponding to spatial discretization formed by microparticle streams correspond to such phenomena of spatial discretization that are similar to those observed in other physical circumstances in microcosm processes, and on the basis of which the term "quantum" appeared and quantum mechanics was created. This phenomenon of spatial discretization has nothing in common either with the classical phenomena caused by the Huygens-Fresnel mechanism of real wave superposition, or with the mathematical illusion of superposition of probability amplitudes determined by virtual trajectories.

Based on this, we can make the main assertion, which will be a partial answer to the third question posed by "**Claude**": **In what direction should thinking proceed to understand these phenomena in a new way?**

Explaining the essence of the diffraction phenomenon corresponding to spatial discretization formed by microparticle streams requires - indicating a new version of its formation mechanism, which will be connected to the fact of scattering on a barrier - as was done by both followers of Newtonian concepts, as well as Grimaldi and Young, and not with mathematical modeling of wave superposition as was done by Fresnel based on Huygens' principle (see (Ganci et al, 2024)).

Understanding in a new way implies indicating an alternative version, for which it will be necessary to search for a large number of empirical facts and conduct their detailed qualitative and quantitative phenomenological analysis.

Through analysis of the discovered facts, it should be possible to explain - why similar phenomena of spatial discretization are observed in the case of corpuscular particles having charge and mass (see e.g. (Bach et al, 2013)) and massless neutral photons.

In these studies, we will probably also have to critically reassess our concepts about photons, which were based on the idea of the existence of ether and were uncritically transferred from Maxwellian mathematical modeling to quantum theories as well. As the superficial analysis of laser beam scattering facts shows us - photons exhibit far more "dynamically rich" properties than is implied for massless and chargeless photons according to quantum field theory. The simplest example of

this is the diffraction of a laser beam photon stream at the isolated boundary of a barrier:

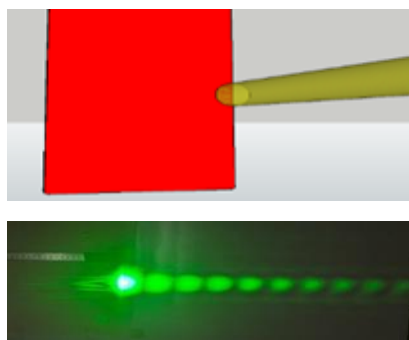


Figure 7.

Similar patterns are not obtained when using all types of laser devices, which indicates that the mentioned phenomenon significantly depends on the physical characteristics of photons as well. Despite this, already based on these patterns, it is possible to express an assumption - the diffraction pattern obtained in the case of one hole corresponds to the cumulative effect of diffractive scattering generated by interferential collision of the light stream at two separate boundaries, while the pattern obtained at two holes corresponds to the cumulative effect of scattering at four separate boundaries. It is possible that these cumulative effects do not correspond to the result of simple additive summation of the corresponding physical characteristics of individual boundary scattering, and particular phenomena of summation may also turn out to be hidden in their formation mechanism. Presumably, this will probably be the case and will be caused by some quantum mechanisms of photon interaction with the atomic structure of the screen. Obviously, to create adequate representations of the existing physical phenomenon, these quantum phenomena will also need to be discovered. When evaluating these new phenomena, it will be fundamentally important to remember the following: if we have to describe their mechanisms within the framework of quantum mechanical representations, we must proceed from a simple assertion - probability amplitude, from the perspective of both quantum and classical representations, represents a characteristic of probability space, which can be connected to real physical characteristics of physical objects through empirical statistical data, and only from quantum considerations, it does not represent any necessity to attribute wave nature to them. The necessity of attributing wave properties should stem from corresponding empirical data, which has never been recorded so far.

The following can be said with confidence: the prospects for research of diffraction-interference phenomena will become even more relevant and interesting.

All authors contributed equally to this research, including conducting experiments, analyzing and discussing results, and preparing the manuscript text.

References

1. Michelson AA, Morley EW. On the relative motion of the earth and the luminiferous ether. *Am J Sci.* 1887;34(203):333-45.
2. Feynman RP, Leighton RB, Sands M. The Feynman lectures on physics, volume III. 3rd ed. Pasadena: California Institute of Technology; 1966.
3. Feynman RP, Hibbs AR. Quantum mechanics and path integrals. Emended ed. New York: McGraw-Hill; 2005. (Original work published 1965)
4. Bohr N. Can quantum-mechanical description of physical reality be considered complete? *Phys Rev.* 1935;48:696.
5. Peng H. [Title not provided]. Research Square [Preprint]. 2021 [cited 2024 Dec]. Available from: <https://doi.org/10.21203/rs.3.rs-237907/v1>
6. Peng H. [Title not provided]. Optica Open [Preprint]. 2024 [cited 2024 Dec]. Available from: <https://doi.org/10.1364/opticaopen.25790460.v2>
7. Young T. The Bakerian lecture: experiments and calculations relative to physical optics. *Philos Trans R Soc London.* 1804;94:1-16.
8. Ganci S, Koch FA. An alternative view of the history of optical diffraction emphasising a neglected observation first reported by Francisco Grimaldi. GSAR Publishers; 2024.
9. Maxwell JC. On Faraday's lines of force. *Trans Cambridge Philos Soc.* 1856;10:27-83.
10. Maxwell JC. A dynamical theory of the electromagnetic field. *Philos Trans R Soc London.* 1865;155:459-512.
11. Bach R, Pope D, Liou SH, Batelaan H. Controlled double-slit electron diffraction. *New J Phys.* 2013;15:033018.
12. The original double slit experiment [Video]. YouTube. 2013 Feb 19 [cited 2024 Dec]. Available from: [https://www.youtube.com/watch?v=\[video_id\]](https://www.youtube.com/watch?v=[video_id])