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Quantum Fluctuation of the Vacuum Offers a Feasible Explanation for all of the Features of the Double Split Experiences

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Abstract

The double split experiences reveal some strange features of nature, which contradict with our everyday experiences. The physics establishment offers a mathematical description of this weird quantum world, but claims that the understanding of the underlying physics is beyond the realm of science. Despite this general skepticism an attempt is made here to unveil the physics of the wave-particle duality and the double-slit experiments.

***Keywords:** Double slit experiments; Wave-particle duality; Particle-field interactions; Quantum vacuum field; Fundamentals of quantum mechanics*

Introduction

Historical Overview

Young conducted the first double-slit experiments with light in 1804 [1]. Based on the observed interference he concluded that the propagating light has wave-like characteristics. The wave characteristic of light could not explain the photoelectric effect. Einstein in 1905 asserted that light is a particle containing energy, which corresponds to their wavelength [2]. Compton (1923) electron scattering confirmed Einstein particle description of light [3]. The particle nature of light can also be concluded from double split experiences. Reducing the intensity of the light significantly, the dim light leaves only a dot on the screen, which is an indicator of a particle. Our current understanding assumes that light consists of photons, which have both wave and particle characteristics. This duality description of light is consistent with the double-slit experiences, which produce an interference fringe even with single photons [4]. De Broglie had extended the wave-particle duality characteristics of photons to electrons and to all matter [5]. He postulated in his PhD thesis in 1924 that all matter has wave properties, that he defined as:

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

where λ the wavelength, h is is the Planck constant, and p is the momentum of the object. The predicted wave-like property of the electron had been confirmed by Davisson and Germer [6]. The first double-slit experiment with a beam of electrons was performed by Claus Jönsson in Germany in 1961 [7]. The outcome of the experiments was consistent with the theoretical predictions,

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producing an interference pattern. The first double-slit experiments with single electrons, passing through the slits one-by-one, were performed by Merli *et al.* in 1976, and Tonomura *et al.* in 1989 [8, 9]. The experiments showed that interference fringes are formed gradually, even when electrons pass through the slits individually. The wave-like property of neutrons was confirmed by the observed interference pattern by Zeilinger *et al.* in 1981 [10]. Since then particle interference has been demonstrated with atoms and molecules as large as carbon-60 and carbon-70, and even to 2000 atoms (25,000 amu) [11]. Single particle interference for antimatter was also demonstrated [12]. Observation of the path of the particles in the single photon and electron experiments diminishes the interference. If all the particles are observed then no interference occurs at all. Based on the percentage of the observed particles any combination is possible between the total and no interference [13, 14].

Experiments and Observations

The double-slit apparatus consists of a thin plate with two closely placed parallel slits, and investigates how light and particles strike the screen behind it (**FIG. 1**). The characteristic features of the experiments are summarized here.

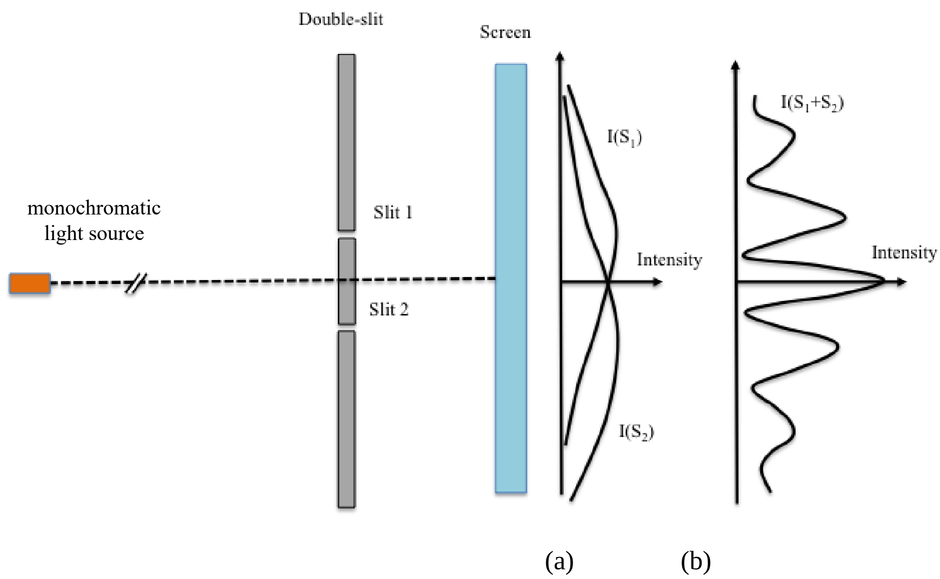

FIG 1. **Experimental set up of the double split experience. (a) The intensity of the light is shown for a single slit opening. (b) The observed intensity is plotted; when both of the slits are open.**

The first experiments were conducted with light, and then with matter particles.

Particles used in the experiments

Photons-light: Monochromatic beam and Single photon

Charged particles: Stream and single

Neutral particles (neutrons, atoms): Stream and single

Antimatter particles: Stream and single

Set ups of the experiments

- One of the slits is open but not both (**FIG. 1(a)**; **FIG. 2(a)**)
- Both slits are open (**FIG. 1(b)**; **FIG. 2(b)**)

- Both slits are open and the position of all of the particles are measured (**FIG. 3**)
- Both slits are open and the position of certain percent of the particles are measured

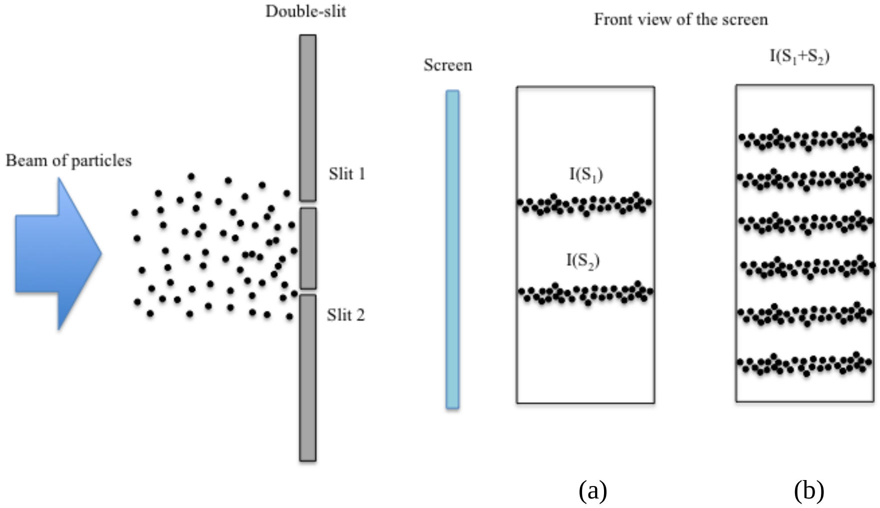

FIG. 2 **Double slit experiences with particles. (a) Distribution of the particles if one of the slits is open. (b) Interference pattern develops when both of the slits are open. The interference pattern develops in case of a single photon or particle as well.**

Outcomes of the experiments

Interference was not observed:

- for all particles (a-d) in experiments A
- for all particles (a-d) in experiments C
- for the measured part of the particles (a-d) in experiments D

Interference occurred:

- for all particles (a-d) in experiments B
- for the not measured particles (a-d) in experiments D

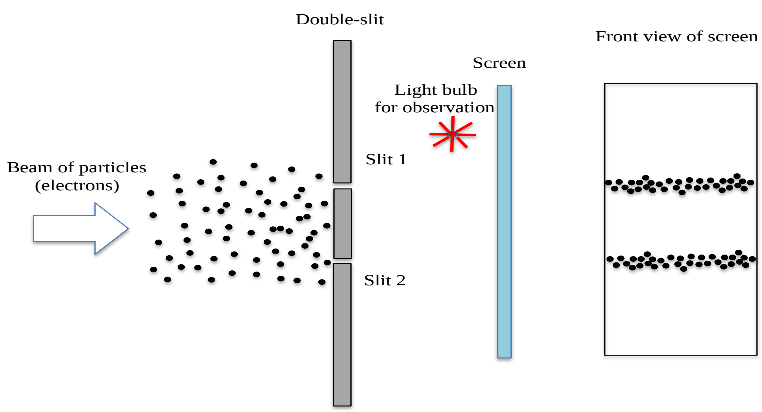

FIG 3. **Upon measurement or observation the interference pattern does not develop despite both the slits being open.**

Any theory needs to explain

- Single particles develop interference pattern when both slits are open,

- This interference is destroyed by measurement,
- The charge of the particles have no effect on the outcome of the experiment,
- Particles hitting the screen have well defined position and momentum despite the developed interference pattern.

Current Interpretation of the Experiments

The current interpretation of the single photon/electron interference is that the photon/electron comes through both of the slits at the same time in order to develop an interference pattern. This is known as the “Copenhagen” interpretation, developed by Niels Bohr, Werner Heisenberg, Max Born and other physicists. The probability distribution of the position of the particles is described by the wave function, which predicts that the single particle can be present at both splits at 50-50 probabilities. Measuring the position of the particles causes the collapse of the wave function, resulting in a well-defined position of the particle. According to this interpretation the particles are waves and exist everywhere, and upon measurement their position can be defined. Thus the wave function is not a real wave, just mathematically describes the probability of the position of the particle. This physical explanation is quite absurd and contradicts with observations, which show that the electron passes through at one of the slits but never both.

It is even more absurd the many-worlds interpretation of quantum mechanics, which holds that there are many worlds, which exist in parallel at the same space and time as our own [15]. These absurd explanations indicate that despite the correct mathematical description, our understanding of the quantum world is still incomplete.

Wave-Particle Duality

There is a consensus in physics, light consists of photons, which have both wave and particle characteristics. Particles of matter exhibit the same wave-particle dual nature. Einstein concluded that the two contradictory pictures of reality; separately neither of them fully explains the phenomena of light, but together they do.

The wave-particle duality concept of light has been deduced from different experiments. Among these experiments, the photoelectric effect and Compton scattering, can be explained exclusively by particle behavior. The experiments, diffraction, interference, and polarization, can only be explained by wave-like behavior. There are experiments, rectilinear propagation, reflection, and refraction, which can be explained by both wave and particle behavior. Experiments indicating either particle or wave behavior but not both are listed in **TABLE 1**.

TABLE 1. **Experiments, which can be explained exclusively by either particle or wave interactions are listed. Experiments in Group 1 can be explained exclusively by particle interaction, and in Group 2. by wave interactions. The characteristic feature of the experiments is that the particles in group 1 interact with matter, while in group 2 with field.**

Group	Experiment	Behavior	Interacting medium	Type of Interaction
1	Photoelectric effect	Particle	Matter	Bulk
	Compton scattering			
2	Interference	Wave	Field	Surface
	Diffraction			
	Polarization			

The experiments, which can be explained only by a single phenomenon (group 1-2), were investigated. The specific feature, which is different in the two kinds of experiments, is the medium what the particle is interacting with. When the particles interact with matter then their behavior can be described as particle. When the particles are interacting with the surrounding "field" this interaction can be described as wave phenomenon. The interaction with matter or with field occurs at the interface of the particle and the medium. The interface is distinctly different when the particle interacts with a field or with matter. The field surrounds the entire particle; therefore, the interaction occurs through the entire surface of the particle, "surface" interaction. The interaction between particle and matter can be described as point-like interaction, or "bulk" interaction. The surface-bulk interactions of particles had been previously proposed to explain the wave-particle duality for atoms [16]. The wave-particle behavior is not exclusive and it is possible that both of the characteristic behaviors of the particles are active.

Vacuum Fluctuation of the Quantum Field

According to the Heisenberg uncertainty principle, tiny fluctuations in the vacuum can occur resulting from the creation and annihilation of particles. The created particle-antiparticle pairs, despite their very short time existence, create a randomly fluctuating dielectric field in the vacuum. This process is described by relativistic quantum field theory, which also predicts that the empty space is filled with fluctuating electromagnetic waves, with all possible wavelengths [17]. The created particle-antiparticle pairs are below the detection limit but their cumulative effect is measurable. The existence of the predicted static quantum vacuum fluctuation has been indicated by various experiments, like the spontaneous decay of higher energy states to ground states, the Lamb shift, and the Casimir force [18, 19]. The dynamical Casimir effect had also been detected [20, 11]. The quantum fluctuation or zero point energy had been directly detected by measuring the quantum noise in circuits [21]. Based on these experiments, the existence of the vacuum fluctuation of the quantum field is well established. Consequently, the effect of this field must be taken into consideration, when one describes the behavior of a particle, which is surrounded by the quantum vacuum field.

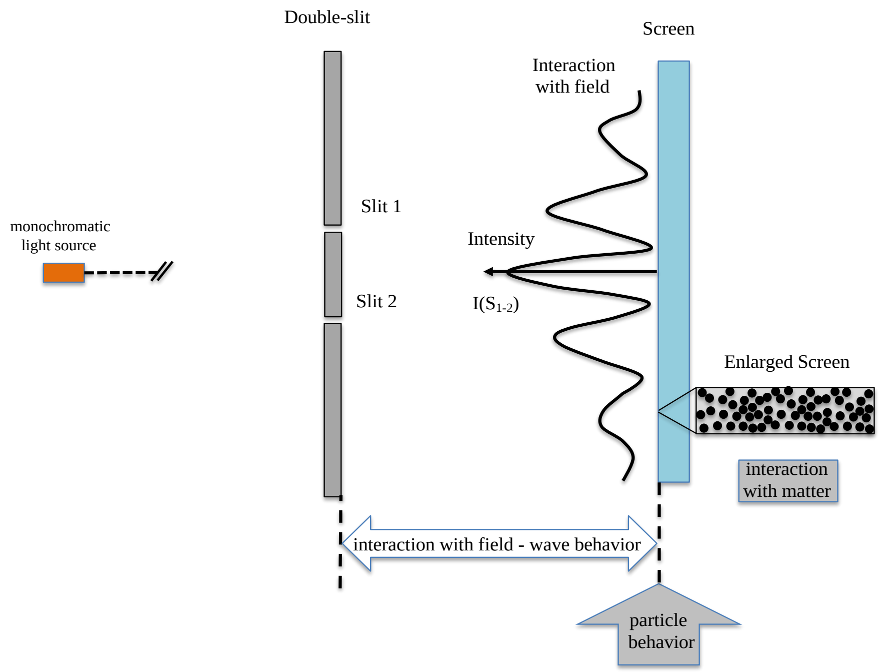

FIG 4. **The surface and bulk interactions of the particles resulting in wave and the particle behavior of photons, or electrons respectively.**

Physical Explanation for the Double Split Experiments

The proposed explanation for the wave and particle behavior is consistent with the outcomes of the double split experiences. As long as the particle, photon or electron, interacts with the field the behavior of the particle can be described as a wave. When the particle hits the screen interacts with matter, then behaves like a particle, with well-defined position and momentum (**FIG. 4**).

When only one slit is open, then the photon/s or particle/s behavior is consistent with the laws of classical physics. Opening the second slit leads to the development of an interference pattern even in the case of a single photon or particle. The question is that what physical conditions have been changed or modified by the opening of the additional slit, leading to the development of interference patterns even for single particle?

The observed interference implies wave behavior for the particle/s. The wave behavior is generated by field interaction. Thus the opening of the second slit should induce a new feature of the field, which was not present/active when only one of the slits was open. It is speculated that the opening of the second slit induces vacuum field fluctuations through the opening. The resonant frequency of these fluctuations interacts with the surface of the particle/s resulting in interference. This speculation is consistent with the measurement effect, which cancels the development of interference. The emitted photons from the instrument interact with the induced vacuum field fluctuation of the particle and override the interference effect. The proposed hypothesis is consistent with experiments, which show that the unobserved part of the single particles still develop an inference pattern [13, 14].

Conclusion

It is suggested that the dual nature of light and particles emerges from the kind of interaction of the particle/s with its surrounding medium. The field-particle interaction can be characterized as "surface" interaction resulting in wave-like behavior. The particle-matter interaction can be characterized as "bulk" interaction resulting in particle-like behavior.

The existence of quantum vacuum field fluctuation is well established, and this effect cannot be dismissed when one describes the behavior of small particles. The proposed quantum vacuum fluctuation-particle interaction model is consistent with all of the features of the double-split experiences, and offers a coherent physical explanation to all quantum effects. The validity of the hypothesis should be testable by shielding the effect of the quantum vacuum fluctuation, preventing the development of interference.

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