VISUAL INTERPRETATION OF THE ELECTRON'S WAVE-PARTICLE DUALITY

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A visual interpretation of the electron's wave-particle duality is presented using the example of known manifestations of its diffraction by a macroscopic object (in particular, a crystal). This interpretation is based on the author's previously established structural features of the electron, which are determined by the balance between Coulomb repulsion and attractive forces, the latter of which are associated with the electron's intrinsic magnetic moment. The carried analysis allows for a more profound and visual understanding of the electron's transformation under certain conditions from a classical "point" state to a bulk quantum "electron cloud" and vice versa. It is noted that the results of this work could not have been obtained on the basis of quantum electrodynamics, which treats the electron as a structureless point particle.

Keywords: point-like free electron, quantum "electron cloud", wave-particle duality, diffraction.
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1. INTRODUCTION

Questions about the structure of the electron arose immediately after the experimental discovery of this key elementary particle by J. D. Thomson in 1897. Attempts to construct a satisfactory theory of the electron were undertaken from the beginning of the 20th century by leading scientists of the time, in particular, H.A. Lorentz and A. Poincaré [1]. However, these studies, conducted in the pre-quantum period, did not establish the reason for the extremely small (effectively point-like) size of a free electron and its resistance to decay due to the Coulomb repulsion forces created by the electron itself. The emergence of the foundations of quantum mechanics in 1925-1930 is associated, to a large extent, with the discovery of previously unknown wave properties of the electron and the presence of its own magnetic and mechanical moments, in addition to mass and charge [2]. The subsequent situation with the mentioned unsolved problems of the electron is reflected by the Nobel Prize winner in physics Max Born who wrote the following on pp. 58-59 of his monograph [3]:

"As the quantum theory developed, physicists became skeptical about definite models of the elementary particles. They preferred therefore to think of the electron, in regard to all external actions, as a charged point mass, without troubling further about its internal structure. The awkward fact remains, however, that the electron's proper energy, which is proportional to e^2/a, becomes infinite when a is put equal to 0."

According to experiments on the ultra-precise determination of the electron's magnetic moment [4], its effective radius does not exceed 10^{-22}m. Therefore, in quantum electrodynamics, the electron is considered as a material point devoid of internal structure, yet possessing mass, charge, and spin, which is associated with the electron's intrinsic magnetic moment.

Using the relations of classical electrodynamics, the interaction of point-like charged particles having intrinsic magnetic moments in vacuum was studied in my short communication [5]. As a result, it was found that, at sufficiently small distances between such like-charged particles, the magnetic attraction between them can exceed their Coulomb repulsion. Based on this, the possibility of fusion of given particles was shown, when the distances between them are smaller than certain critical values. Furthermore, in my paper [5], it was established that the integrity and extremely small (practically point-like) size of a free electron is due to the presence of its intrinsic magnetic moment. This result also explains the well-known paradox of the infinitely large self-energy of the electron [6].

This paper presents a visual interpretation of the electron's wave-particle dichroism. This interpretation is based on the structural features of the electron described in my article [5], which are determined by the balance between the Coulomb repulsive and attractive forces, the latter of which are associated with the electron's intrinsic magnetic moment.

2. ON DISCOVERY AND APPLICATIONS OF THE WAVE PROPERTIES OF ELECTRONS

In 1924, the French physicist Louis de Broglie hypothesized that all matter could be represented as a wave, later called a de Broglie wave, in the manner of light [2]. That is, under appropriate conditions, electrons and other matter would exhibit the properties of either particles or waves. Indeed, in 1927, G.P. Thomson discovered that the diffraction effect characteristic of light occurs when a beam of electrons passes through the thin metal foil, and the American physicists C.J. Davisson and L.H. Germer discovered it by reflecting electrons from the nickel single crystal [2]. Subsequently, the established wave properties of electrons became the basis for electronographic methods for studying the atomic structure of various objects in molecular biology, the physical chemistry of natural and synthetic polymers, semiconductors, and other materials [7-9]. Electron diffraction methods

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involve the diffraction of electrons, which, under certain conditions, exhibit these wave properties when interacting with matter. This interaction results in the formation of individual diffracted electron beams. The intensities and spatial distribution of these beams are strictly dependent on the atomic structure of the sample, the size and orientation of individual crystals, and other structural parameters. Electron diffraction studies are conducted in specialized instruments—electronographs and electron microscopes—where, under vacuum conditions, electrons are accelerated by an electric field, focused into a narrow, high-aperture beam, and the resulting beams, after passing through the sample, are either photographed (electron diffraction patterns) or recorded by a photoelectric device [7-9].

3. ON THE STRUCTURE OF A FREE ELECTRON

A free electron is currently considered as an indivisible, point-like elementary particle, and its possible constituent parts are still unknown [10]. However, based on the analysis, carried out in paper [5], it is possible to understand the previously unexplained reason for the extremely small (effectively point-like) size of a free electron and its resistance to decay due to the electron's self-generated Coulomb repulsion forces. Indeed, the electron's intrinsic magnetic moment is clearly determined by its internal magnetic structure. This structure is formed in such a way that the potential energy of a stable free electron is minimized. This can only occur due to magnetic attraction forces within the electron. According to the results of paper [5], such attraction is much stronger than Coulomb repulsion at sufficiently small distances, characteristic, in particular, for the electron's size. Thus, this magnetic attraction between possible fragments of a free electron not only prevents the electron from decaying into such fragments but also constricts its volume to an extremely small value, the lower limit of which has not yet been established. According to the paper [5], this result also explains the well-known paradox of the infinitely large self-energy of the electron [6].

4. INTERPRETATION OF ELECTRON DUALISM

According to the results of the author's article [5], described in the previous section 3, the structure of the electron is largely determined by the balance between its internal forces of Coulomb repulsion and magnetic attraction, the latter of which are associated with the presence of an intrinsic magnetic moment of the electron. In the case of a free electron in a vacuum, such a balance of forces leads to an extremely small (practically point-like) volume of the electron, in which its entire mass, charge and magnetic moment are concentrated [4]. However, when such an electron interacts with other objects or is significantly affected by external fields, such a balance of forces can be disrupted. As a result, the unbalanced electric charge and the associated mass of the electron "spread" from the point state into a many times more voluminous electron cloud. Naturally, the behavior of such a cloud, unlike a point electron, can no longer be described within the framework of classical mechanics and is an object of study in quantum physics, where the state of this cloud as a whole is characterized by a wave function [2].

Figure 1 shows the scheme of these possible transformations of an electron as it falls from a vacuum onto an object and then returns from the object to a detector, which is also located in a vacuum. Similar processes, for example, occur during electron diffraction by a crystal, where the wave properties of the electron, described in Section 2, become significant. According to Figure 1, when an electron falls from a vacuum onto an object, it "expands" from a point state into a three-dimensional electron cloud, which exhibits quantum wave properties, interacting simultaneously with a fairly large number of atoms in the object. However, upon the electron's subsequent return to the vacuum, it again narrows to a virtually point-like "classical" state, which is ultimately detected by the detector, for example, as a dot on a screen. Naturally, the position of this dot will be determined by the quantum-mechanical interactions of the electron in question within the object, although in its initial and final positions, this electron behaves like a classical point particle in a vacuum. Thus, for example, when a sufficiently large number of electrons fall on a crystal, a characteristic diffraction pattern is formed on the detector screen, caused directly by the wave properties of the electrons [7-9].

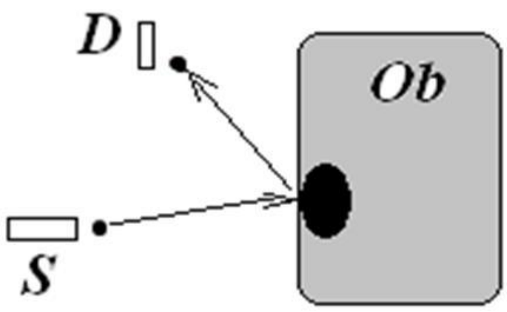

Fig. 1. Schematic representation of an electron falling from the source (***S***) onto the object (***Ob***) and then its arriving from this object at the detector (***D***). The electron, marked in black, is a point particle in a vacuum outside the object, while inside the object it expands, forming a three-dimensional electron cloud.

5. CONCLUSIONS

Quantum electrodynamics (QED) is one of the most successful theories in the history of physics, as it allows for the calculation of many particle and field interactions in the microscopic world with exceptional accuracy [2,6]. However, the scope of QED's application is limited, as it treats the electron as a point particle. Thus, QED fails to explain not only the small (practically point-like) size of the electron, but also its resistance to decay due to the extremely strong Coulomb repulsion forces that arise within it. Furthermore, this leads to the well-known paradox of the infinite self-energy of such a point-like electron [6].

At the same time, in the paper of the author [5], it was shown that the integrity and extremely small (practically point-like) size of a free electron in vacuum is due to the presence of its intrinsic magnetic moment. This result also explains the mentioned paradox of the infinitely large self-energy of the electron. It has been established that the point-like size of a free electron is due to the significant dominance of magnetic attraction forces over Coulomb repulsion [5]. However, as shown in this paper, this balance of forces can be disrupted when an electron interacts with other objects or is significantly affected by external fields. As a result, the unbalanced electric charge and associated mass of the electron "spread" from the initial point state into a much larger electron cloud, which is described within the framework of quantum physics. Thus, Section 4 presents a visual interpretation of the wave-particle duality of the electron, associated with its transition from the classical state to the quantum state and vice versa.

I believe that further development of research connected with an electron structure will allow for a deeper understanding of the nature of quantum mechanical phenomena, including the essence of hidden parameters and wave function collapse of such micro-particles.

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