Some Properties of Electrons

Ilgaitis Prūsis[1,] Peteris Prūsis[2]

Abstract

The electron is the most widely used elementary particle and at the same time the least studied. It is known that the electron has mass, charge, and spin. The article shows that an electron moves along a complex trajectory, the main components of which are chaotic thermal motion, zitterbewegung, and the direction determined by the external electric field. The trajectory of an electron can be mathematically described as a wave, but from this QM draws the incorrect conclusion that the electron itself is a wave. What is mentioned in the article also applies to protons, neutrons, and other elementary particles.

Keywords: physics, electron, Zitterbewegung, electricity, magnetism, nuclear physics, Unified Field Theory, QM, elementary particles.
PACS Classification codes:
01.55.+b General physics; 04. General relativity and gravitation; 03.50.-z Classical field theories; 12.10.-g Unified field theories and models

[1] Independent researcher;
[2] Independent researcher

Introduction

Electrons are known to have mass, charge, and spin. Everything else is an assumption upon which the theoretical considerations of quantum mechanics (QM) are based, including wave-particle duality, which states that the electron exists as a standing wave that has no fixed location at any moment, i.e., the electron is smeared out in space.

Experiments show that electrons participate in different motions simultaneously and therefore their motion forms a complex trajectory. Below we will look at the main types of movement and the effects they cause.

Thermal movement

Thermal motion is caused by electron collisions with atoms in the crystal lattice, which oscillate under the influence of heat. The higher the temperature, the greater the amplitude of the oscillations. Thermal fluctuations are completely chaotic and therefore characterized by a Boltzmann distribution and an average velocity. At absolute zero, there is no thermal motion. By colliding with the atoms of the lattice, electrons transfer heat. Electrons are the main heat carriers. The most free electrons are in silver. Therefore, silver is the best conductor of heat and electricity.

Drift

Drift is the movement of an electron in an electric field. The drift velocity is characterized by the mobility of electrons, which depends on crystal lattice defects, phonons, impurities, field strength and other factors that scatter electrons. If there is no external electric field, then there is no electron drift and they move chaotically in all directions.

Zitterbewegung

Zitterbewegung [1,2,6] is the rapid circular oscillation of electrons around the center of equilibrium. They were predicted by Breit and Schrödinger when analyzing the Dirac equation. Now they have been experimentally proven. The angular frequency of electron rotation is very high: $\omega = 2mc2/\hbar$. Experimentally detected frequencies range from 10^{15} to 10^{30} Hz [3,4,5]. The amplitude of the oscillations is limited by Planck's law: $E°=°hf$, where: E - energy of electron, where:

h - Planck's constant,

f – frequency.

If the energy is equal to or greater than this limit, the electron emits it as a photon. If it is less, then it determines the amplitude of the zitterbewegung (Fig. 1).

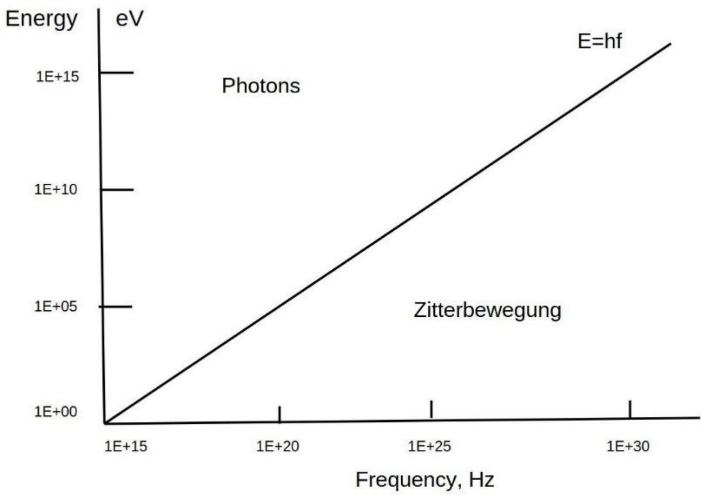

Fig.1. Electron energy and vibration amplitude.
Planck's law defines the boundary between zitterbewegung oscillations and photon production.

The cause of the Zitterbewegung oscillations is the electromagnetic field around the electron. This is described by Maxwell's equations. As an electron moves, the electric field in space changes. Any change in the electric field causes a corresponding magnetic field to be generated according to: $\delta \boldsymbol{E}/\delta t = c(\blacktriangledown \times \boldsymbol{B})$,

where: $\boldsymbol{E}$ – strength of electric field,

c – velocity of light,

$\boldsymbol{B}$ – strength of magnetic field,

▼ – Nabla operator.

A change in the magnetic field creates an electric field: $\delta \boldsymbol{B}/\delta t = - (\blacktriangledown \times \boldsymbol{E})$.

This creates an exotic electromagnetic field that is closely related to the electron and causes it to oscillate. Planck's law prohibits the electron from escaping by radiation, so the oscillations can continue indefinitely. The electron can be said to be in a potential well created by its oscillations.

The zitterbewegung (shaking motion) continues even at $0K$ (absolute zero) temperature.

Orbital motion

In an atom, electrons move along surfaces formed by allowed energy levels. In the simplest case, in an H or He atom, these surfaces are spheres with the atomic nucleus at their center. Bohr orbitals are the intersections of these spheres. At the same time, the electron performs a zitterbewegung oscillation. Therefore, the electron trajectory is a complicated 3D spiral. Only in the simplest case in the H atom are the electron oscillations sinusoidal, and even then, they can contain different harmonic components simultaneously. In all other cases, the shape of the spiral is influenced by the other electrons. The amplitude of the zitterbewegung oscillations can be geometrically comparable to the dimensions of an atom, yet without exceeding the limits of either the allowed energy level or Planck's law.

Conclusions

The electron is practically always in the zitterbewegung oscillation mode. This explains many QM problems, including the interference pattern in the Davisson-Germer experiment [7] and the observer effect in the double-slit experiment. Therefore, there is no reason to believe that an electron is a wave [8].

An electron moves along a complex, well defined trajectory. Theoretically, there is no obstacle to measuring it with the necessary precision. Another question is whether we have the tools necessary for such measurement.

Of course, the motion of an electron can also be described as a wave, as de Broglie and Heisenberg do, and probability densities can be used instead of the electron trajectory, but such a mathematical model will only depict some of the properties of the electron. Similar to wave-like motion, the Moon's motion around the Sun can be described and the probability of the Moon's location in the sky can be determined with great accuracy, but this will be far from reality.

The same applies to all other fermions.

The above does not mean that QM is wrong. QM is simply one of the possible theoretical models of the electron and like all models it only reflects part of reality or, in A. Einstein's words - QM is incomplete.

This article only reflects some of the peculiarities of electron motion. The main question of what an electron is and what its structure is remains open.

References

1. Breit, Gregory *(1928). "An Interpretation of Dirac's Theory of the Electron". Proceedings of the National Academy of Sciences.* ***14*** *(7): 553–559. Bibcode:1928PNAS...14..553B. doi:10.1073/pnas.14.7.553*
2. *Leblanc, L. J. at all (2013). "Direct observation of zitterbewegung in a Bose–Einstein condensate". New Journal of Physics.* ***15*** *(7): 073011. arXiv:1303.0914*
3. *Shi, L. at all. (2013). "Anomalous Electron Trajectory in Topological Insulators". Physical Review B.* ***87*** *(16): 161115. arXiv:1109.4771*
4. *Schliemann, J. (2005). "Zitterbewegung of Electronic Wave Packets in III-V Zinc-Blende Semiconductor Quantum Wells". Physical Review Letters.* ***94*** *(20): 206801. arXiv:cond-mat/0410321*

5 *Katsnelson, M. I. (2006). "Zitterbewegung, chirality, and minimal conductivity in graphene". The European Physical Journal B.* ***51*** *(2): 157–160. arXiv:cond-mat/0512337*

6. Hestenes, D. The zitterbewegung interpretation of quantum mechanics. https://www.researchgate.net/publication/225198668_The_zitterbewegung_interpretation_of_quantum_mechanics.
7. Davisson, C.; Germer, L. H. (1927). *"The Scattering of Electrons by a Single Crystal of Nickel". Nature.* ***119*** *(2998): 558. Bibcode:1927Natur.119..558D. doi:10.1038/119558a0*
8. Prūsis, I.; Prūsis, P. About wave-particle duality. https://www.researchgate.net/publication/334896014_About_wave-particle_duality

Acknowledgements: We are very grateful to Ieva Mazere for valuable discussions, providing comfortable working conditions and delicious meals.

Correspondence and requests for materials should be addressed to I.P. (ilgaitis@gmail.com).