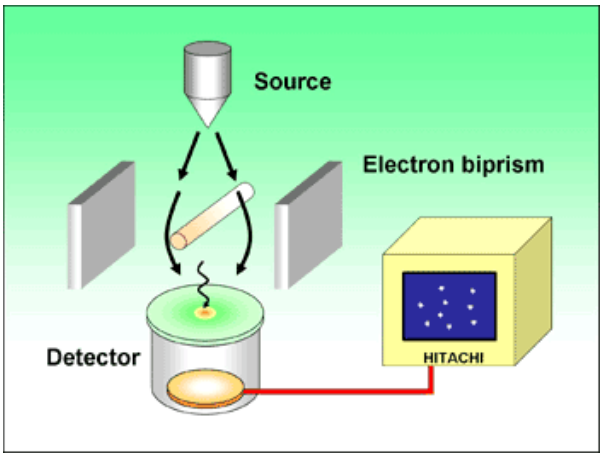
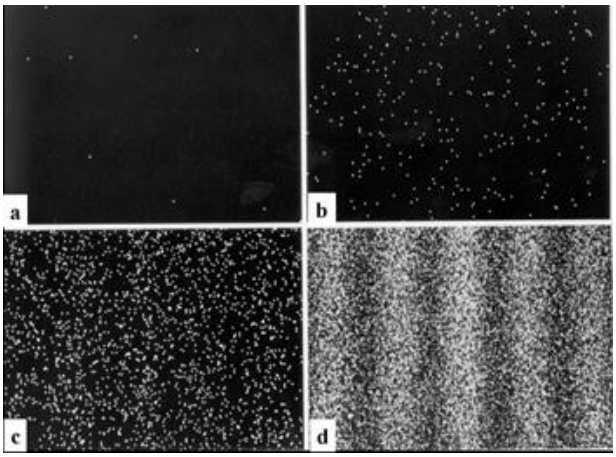
Against Wave-Particle Duality Concept
The Electron Double-Slit Experiment

by Hamid – August 2010

The electron double-slit experiment was eventually performed in 1961, by Claus Jönsson of Tübingen; during a fellowship at the University of Tübingen in 1973 and 1974, Tonomura worked with Gottfried Möllenstedt, who was the first researcher to observe electron interference patterns (*electron diffraction patterns*) by developing electron biprism interferometers; the single electron double slit experiment was performed by Pier Giorgio Merli, Gian Franco Missiroli and Giulio Pozzi in Bologna in 1974, and repeated by Akira Tonomura and co-workers at Hitachi in 1989. The effort of these researchers is in fact an important step toward rejecting the existing unrealistic concept in quantum mechanics, namely "wave-particle duality" which is known as ***Complementarity principle*** in Copenhagen Interpretation.





http://www.hitachi.com/rd/portal/research/em/doubleslit.html
http://www.youtube.com/watch?v=oxknfn97vFE&feature=related

Let us concentrate our attention on the final words of **Akira Tonomura** about the outcomes of experiment that was carried out at Hitachi:

"We have reached a mysterious conclusion. Although electrons were sent one by one, interference fringes could be observed. These interference fringes are formed only when electron waves pass through on both sides of the electron biprism at the same time but nothing other than this. Whenever electrons are observed, they are always detected as individual particles. When accumulated, however, interference fringes are formed. Please recall that at any one instant there was at most one electron in the microscope. We have reached a conclusion which is far from what our common sense tells us."

According to a principle in physics, interference is the addition (superposition) of two or more waves resulting in a new wave pattern. Consequently, it is believed that in double-slit experiment the fringes are formed due to interference of two combining waves, such as: light waves, photon waves, matter waves or even electron waves! But, is it really possible to have an interference pattern when electrons were sent one by one in the electron double-slit experiment? No, it isn't. On the other hand, how can an electron interfere with itself? It must be more questionable for those who think, without any scientific basis, particles such as photons or electrons have wave-like behaviour as well.

Anyhow, the fringes are formed and even observable. We need therefore to find the cause of formation of fringes in double-slit experiment.

Before investigation into the reason of formation of double-slit pattern, it would be helpful to have a relatively clear picture about the emitter of electrons in this experiment. Usually electron microscopes utilize an electron source with a Thermionic Gun in which electrons are released from a resistively-heated tungsten filament (cathode). In other words, by heating the filament the most energetic electrons of tungsten atom, which gather in outermost orbital, gain sufficient energy to overcome the work function barrier and move toward the anode. These electrons later used for imaging are emitted from a nearly perfect point source (the space charge). Therefore, it is reasonable to conclude that the bright spots on the monitor represent at random positions the outer orbital electrons of a huge number of tungsten atoms. It should be reminded that generally it is told the atom of tungsten has only two electrons in its outermost orbital.

In order to make clear what we are talking about, it is necessary to refer to the new probability wave function which for the first time was introduced in my previous article titled *"**Wave Function, Developed Gaussian Distribution**"*, published in ***toequest.com,*** September 2008.

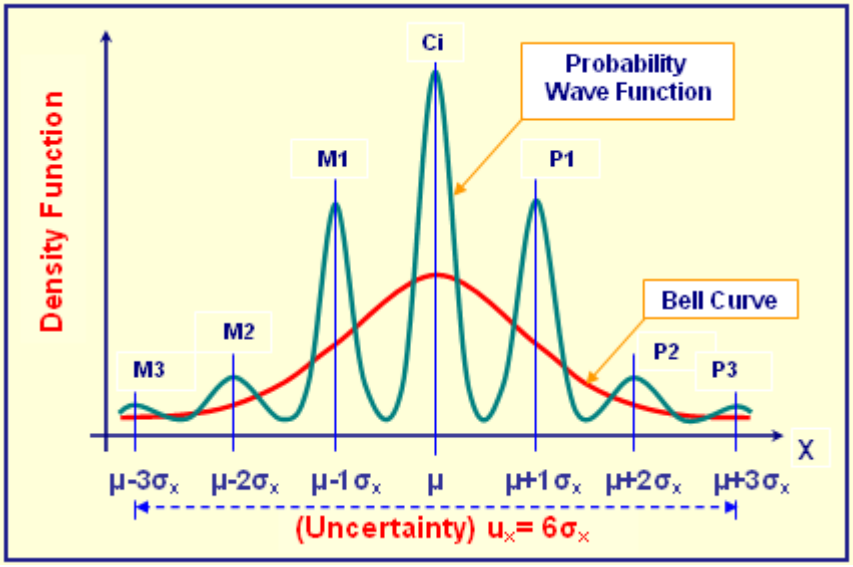


Figure 1

To adapt this new function to the electron configuration of tungsten atom in general and its outer orbital specifically, some explanations are needed here:

1) The quantum variable in this specific case is the energy of an electron which can be represented by **E**, instead of **X.**
2) Uncertainty in the electrons' energy of tungsten atom is equal to $6\sigma_E$. In other words, if we would know or measure the maximum and minimum energy of electrons in the atom of tungsten, then $u_E = E_{max} - E_{min} = 6\sigma_E$, which encompasses almost all electrons (99.73%).
3) Uncertainty in the electrons' energy of first-order orbitals (electron clouds), namely M2, M1, Ci, P1 and P2, is the same and equal to σ_E. These orbitals together with M3 and P3 make the first-order quantum structure (ground state) of electron configuration of an atom. From now on, it is better to indicate them more accurately, such as: ^{1}M3, ^{1}M2, ^{1}M1, ^{1}Ci, ^{1}P1 and so forth.
4) The average electrons' energy in tungsten atom is μ and $\mu = (E_{max}+E_{min})/2$.

5) The function states that no two electrons in a single orbital and also in the same atom can have the same energies.
6) The energy level of each orbital can be defined by the average electrons' energy in that specific orbital, for example: $(\mu\text{-}1\sigma_E)$ for ^{1}M1.
7) The interval between energy levels of first-order nearest neighbor orbitals of an atom is the same and equal to σ_E. The interval between energy levels of second-order adjacent orbitals is $1/6\sigma_E$, between energy levels of third-order adjacent orbitals is $(1/6)^2\sigma_E$, and so on.
8) In the electron configuration or electron pattern of tungsten atom each electron occupies a definite and exclusive position. The distance of every electron from a vertical reference line, such as the centerline of pattern which coincides to the mean value or mathematical expectation (μ), determines both the position and the energy of each individual electron simultaneously. These two physical properties have direct relation with each other. If the reference line runs through the zero point (E=0), that represents the position of tungsten atom's nucleus, the distance of each electron from reference line is the radius of exclusive spherical shell of that electron around the nucleus. In other words, only one electron could exist in each shell.
9) Taking into consideration that the atom of tungsten has 74 electrons, the two electrons of outermost orbital belong to first-order electron cloud ^{1}P2 which has the highest energy level in this case.

For more clarification on this topic further quantification is necessary. In fact, what we see on the pattern of this beautiful experiment are small spots being made up from a many of individual particle impacts. These particles are the two electrons of first-order electron orbital ^{1}P2 of myriad tungsten atoms of cathode. A very high precise double abscissa scale on the pattern could be used for measuring, at the same time, both the position and the energy of each individual electron. In this case the centerline of scale could be the centerline of pattern which runs through the middle or the energy level of ^{1}P2, namely $\mu+2\sigma_E$, Figure 2.

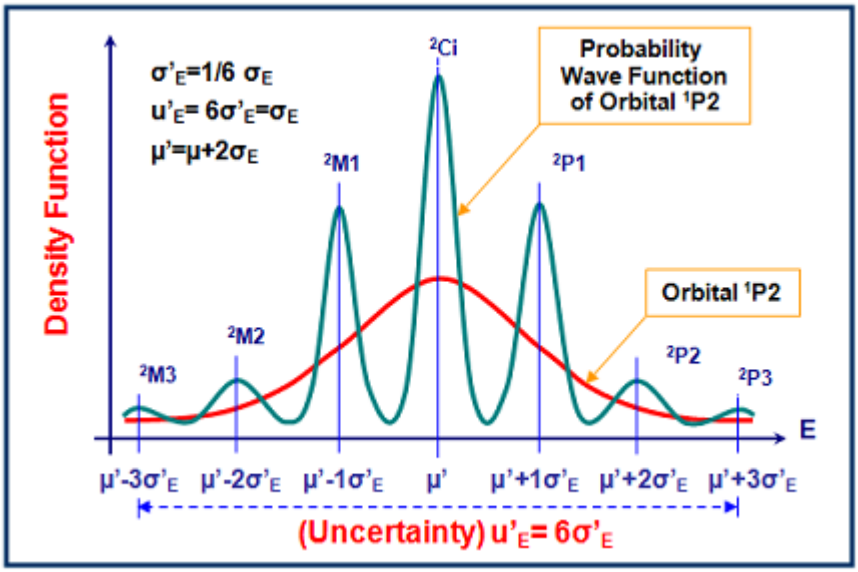


Figure 2

At this point, it would appear that we have gained a wonderful opportunity to find out the glory of this experiment, and also to evaluate once again the abilities of the new probability wave function.

The five visible fringes on the pattern represent the sub-quantum structure of orbital ^{1}P2 in which the most observable sub-orbitals are ^{2}M2, ^{2}M1, ^{2}Ci, ^{2}P1, and ^{2}P2. In this case, the interval between energy levels of adjacent electron clouds is $1/6\sigma_E$. The pattern is undoubtedly compelling evidence that each of two electrons of a tungsten atom's outermost orbital could belong to either one of the sub-orbitals ^{2}M2, ^{2}M1, ^{2}Ci, ^{2}P1 or ^{2}P2, because we can observe all related fringes on the monitor. It should be reminded that the bright spots represent those electrons which have been emitted from a huge number of tungsten atoms. From probabilistic point of view, it is impossible to predict the exact location of these two electrons of ^{1}P2 in a tungsten atom. It can only be specified by means of measurement using for example a double abscissa scale on the pattern.

Here, it would be better to clarify that several electrons can enter into each orbital or sub-orbital, but only an individual electron could exist in each shell. Furthermore, chain coding may be used to indicate sub-orbitals briefly, such as: **^{1}P2-^{2}M1-^{3}Ci** for sub-orbital ^{3}Ci of sub-orbital ^{2}M1of orbital ^{1}P2. Generally speaking, the pattern of this experiment shows us very obviously the classification of electrons and also the differences which exist between these particles. Therefore, the pattern should be named "*diffraction pattern*" instead of "*interference pattern*" which is a false name in this case. As a matter of fact, in all kinds of double-slit experiment we encounter only with *diffraction phenomenon*. This subject has been discussed before in my article titled *"Double-Slit Experiment and Quantum Mechanics"*, published in ***toequest.com***, November 2005.

In this experiment the two electrons of all tungsten atoms of emitter together, make a collection of quantum variables (^{1}P2) that are within the range $(\mu+2\sigma_E)\pm0.5\sigma_E$ with an uncertainty equal to the standard deviation of the whole electron distribution of a tungsten atom, namely σ_E. It is interesting to mention that these variables as a group and, in an atom, all electrons as a whole follow the same rule.

The outcomes of electron double-slit experiment give it a glorious and valuable position in quantum mechanics. Because it enables us to examine the correctness of *the new probability wave function* with higher accuracy or a narrower uncertainty range, and also to be more confident that this function is applicable to measurement results related to all natural phenomena.

This accurate experiment is without doubt a convincing and strong reason for declaring as invalid the so called *wave-particle duality* which is a wrong and misleading concept in the most widely-accepted interpretation of quantum mechanics. Thanks to all the institutions, organizations and individuals that have made efforts to develop and improve the electron double-slit experiment.

Anyone who wants to understand the world more deeply and accurately must dominate the language of the mathematicians at least in its basics.

Notes:

- **The German version of this article can be found at:**
  Gegen das Konzept des Welle-Teilchen-Dualismus
- **The Persian version of this article can be found at:**
  علیه مفهوم دو گانگی موج- ذرّه