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Research Article

The *Zitterbewegung* Interpretation of Quantum Mechanics as Theoretical Framework for Ultra-dense Deuterium and Low Energy Nuclear Reactions

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Abstract

This paper introduces a *Zitterbewegung* model of the electron by applying the principle of Occam's razor to the Maxwell's equations and by introducing a scalar component in the electromagnetic field. The aim is to explain, by using simple and intuitive concepts, the origin of the electric charge and the electromagnetic nature of mass and inertia. The *Zitterbewegung* model of the electron is also proposed as the best suited theoretical framework to study the structure of Ultra-Dense Deuterium (UDD), the origin of anomalous heat in metal–hydrogen systems and the possibility of existence of "super-chemical" aggregates at Compton scale.

Keywords: Clifford algebra, Compton scale aggregates, Dirac equation, Electric charge, Electron structure, Elementary particles, LENR, Lorenz gauge, Maxwell's equations, Occam's razor, Space–time algebra (STA), Ultra-dense deuterium, Vector potential, Weyl equation, *Zitterbewegung*

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1. Introduction

Prof. David Hestenes, emeritus of the Arizona State University, is the most notable and active physicist that advocates the use of geometric algebra in physics [1]. Space–time geometric algebra is a four dimensions real Clifford algebra with Minkowski signature "$+ - --$" ($Cl_{1,3}(\mathbb{R})$) or with signature "$- + ++$" ($Cl_{3,1}(\mathbb{R})$).

Hestenes rewrote Dirac's equation for the electron using space–time algebra $Cl_{1,3}(\mathbb{R})$, eliminating the unnecessary complexities and redundancies arising from the traditional use of matrices and complex algebra. As a matter of fact, the Dirac gamma matrices γ_μ and the associated algebra can be seen as an isomorphism of the four basis vector of space–time geometric algebra. This simple isomorphism allows a full encoding of the geometric properties of the Dirac algebra, and a reformulation of the Dirac equation that does require neither complex numbers nor matrix algebra.

In this context the wave function ψ is characterized by eight real values of the even grade multivectors of space–time algebra (STA). The even grade multivectors of STA can encode ordinary rotations as well as Lorentz transformations in the six planes of space–time. Hestenes associates the rotations encoded by the wave function with an intrinsic characteristic of the electron: the *Zitterbewegung*, a German word for "trembling motion", indicating a rapid rotation that is considered at the origin of both the electron spin and its magnetic moment. Hestenes considers the complex phase of the wave function, solution of the traditional Dirac equation, as the phase of the *Zitterbewegung* (ZBW) rotation, showing "*The inseparable connection between quantum mechanical phase and spin*" [2,3]. Consequently, he rejected the "*conventional wisdom that phase is an essential feature of quantum mechanics, while spin is a mere detail that can often be ignored*" [2].

In this paper we will try to show that the application of Occam's razor principle to the Maxwell's equations advise a particular ZBW interpretation of quantum mechanics proposed by Hestenes [4]. A very simple ansatz based on STA and on a reinterpretation of the "Lorenz gauge" is proposed to explain the origin of the electric charge and the electromagnetic nature of mass and inertia. A ZBW model of the electron is introduced in a preliminary attempt to explain the structure of Ultra-dense Deuterium (UDD) [5,6] and the origin of Anomalous Heat in metal–hydrogen systems. According to this framework, the electron structure consists of a massless charge distribution that rotates at the speed of light along a circumference with a length equal to electron Compton wavelength ($\simeq 2.42631$ pm). The electron mass-energy, expressed in natural units (NU), is equal to the angular frequency of the ZBW rotation and to the inverse of the orbit radius (i.e. 511 keV). The inter-nuclear distance in UDD of $\simeq 2.3$ pm, found by Holmlid [5], seems to be compatible with proton-electron structures at Compton scale where the ZBW phases of neighbor electrons are synchronized. The existence of structures at an intermediate scale between atomic dimensions/energies and nuclear ones have been proposed by many authors [7–9]. These hypothetical composites are electrically neutral or negatively charged objects that are not repelled by the Coulomb barrier. These structures may generate unusual nuclear reactions and transmutations, considering the different sizes, time-scales and energies of these composites with respect to the dimensions of the particles (like neutrons) normally used in nuclear experiments.

2. Maxwell's Equations with Occam's Razor

The STA can be represented by the four dimensions real Clifford algebra $Cl_{3,1}$, with signature "$- + ++$", where the standard Euclidean metric is used for spatial coordinates. In this algebra the four unitary basis vectors $\gamma_x, \gamma_y, \gamma_z$ and γ_t are isomorphic to Majorana matrices and the following rules apply:

$$\gamma_i\gamma_j = -\gamma_j\gamma_i \quad \text{with} \quad i \neq j \;\; i,j \in \{x,y,z,t\}, \tag{1}$$

$$\gamma_x^2 = \gamma_y^2 = \gamma_z^2 = -\gamma_t^2 = 1. \tag{2}$$

Using this algebra, Maxwell's equations can be rewritten in a compact form starting from the derivatives of the electromagnetic four-potential [1,10]

$$\boldsymbol{A}_{\square} = \gamma_x A_x + \gamma_y A_y + \gamma_z A_z + \gamma_t A_t. \tag{3}$$

The four vector potential components A_x, A_y, A_z and A_t are functions of the space–time coordinates x, y, z, t and have dimension in SI units equal to (V s m^{-1}), and have the dimension of an energy expressed in eV (electron volts) in natural units (NU), where $\hbar = c = 1$.

$\boldsymbol{A}_{\square}$ can be seen as a vector field in the space–time continuum and as the unique source of all concepts-entities in Maxwell's equations [11]. We remember that the vector potential should not be viewed only as a mathematical tool but as a real physical entity, as suggested by the Aharonov–Bohm effect [12], a quantum mechanical phenomenon in which a charged particle is affected by the vector potential in regions in which the electromagnetic fields are null.

Using the following definition of the operator $\boldsymbol{\partial}$ in STA

$$\boldsymbol{\partial} = \gamma_x \frac{\partial}{\partial x} + \gamma_y \frac{\partial}{\partial y} + \gamma_z \frac{\partial}{\partial z} + \gamma_t \frac{1}{c}\frac{\partial}{\partial t} = \nabla + \gamma_t \frac{1}{c}\frac{\partial}{\partial t}, \tag{4}$$

the following expression can be written:

$$\boldsymbol{\partial}\boldsymbol{A}_{\square} = \boldsymbol{\partial} \cdot \boldsymbol{A}_{\square} + \boldsymbol{\partial} \wedge \boldsymbol{A}_{\square} = S + \boldsymbol{F} = \boldsymbol{G}, \tag{5}$$

where $S = \boldsymbol{\partial} \cdot \boldsymbol{A}_{\square}$ and $\boldsymbol{F} = \boldsymbol{\partial} \wedge \boldsymbol{A}_{\square}$. This means that the electromagnetic field $\boldsymbol{G}$ is a composition of a scalar (grade zero element of $Cl_{3,1}$) field S and a six components bivector (grade two elements of $Cl_{3,1}$) field $\boldsymbol{F}$. Calling I the pseudoscalar unity of $Cl_{3,1}$

$$I = \gamma_x \gamma_y \gamma_z \gamma_t \tag{6}$$

and $c = 1/\sqrt{\epsilon_0 u_0}$ the speed of light, a simple relation between the electric field $\boldsymbol{E}$, the flux density field $\boldsymbol{B}$ and the bivector field $\boldsymbol{F}$ is found:

$$\boldsymbol{F} = \frac{1}{c}\boldsymbol{E}\gamma_t + I\boldsymbol{B}\gamma_t = \frac{1}{c}\left(\boldsymbol{E} + Ic\boldsymbol{B}\right)\gamma_t. \tag{7}$$

Table 1 represents the relation between the fundamental electromagnetic entities and the space–time components of the vector potential $\boldsymbol{A}_{\square}$.

Using the so called "Lorenz gauge" ($S = \boldsymbol{\partial} \cdot \boldsymbol{A}_{\square} = 0$) or using the "Coulomb gauge" ($S_i = 0,\ i = 1, 2, 3, 4$) the scalar component S of electromagnetic field $\boldsymbol{G}$ is ignored and its physical meaning is lost. The Occam's razor principle states that "plurality should not be posited without necessity" and according to this rule the number of independent concepts or entities in mathematical models should be reduced as much as possible. For this reason it's important to have a direct derivation of the concepts of "charge density" and "current density" from the electromagnetic

Table 1. Relation between electromagnetic entities and the vector potential (electromagnetic tensor).

$\boldsymbol{\partial}\boldsymbol{A}_{\square}$	$\gamma_x A_x$	$\gamma_y A_y$	$\gamma_z A_z$	$\gamma_t A_t$
$\gamma_x \frac{\partial}{\partial x}$	S_1	B_{z1}	$-B_{y1}$	$\frac{1}{c}E_{x1}$
$\gamma_y \frac{\partial}{\partial y}$	B_{z2}	S_2	B_{x1}	$\frac{1}{c}E_{y1}$
$\gamma_z \frac{\partial}{\partial z}$	$-B_{y2}$	B_{x2}	S_3	$\frac{1}{c}E_{z1}$
$\gamma_t \frac{1}{c}\frac{\partial}{\partial t}$	$\frac{1}{c}E_{x2}$	$\frac{1}{c}E_{y2}$	$\frac{1}{c}E_{z2}$	S_4

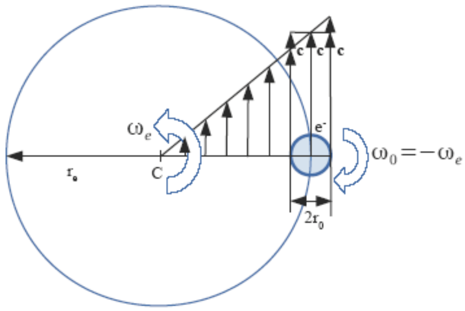

Figure 1. *Zitterbewegung* model and speed diagrams of the free electron. All points of the sphere have an absolute speed equal to c.

four-potential $\boldsymbol{A}_\square$ reducing, in this manner, the primitive essential concepts used in Maxwell's equations to a unique entity. This aim can be accomplished if we recognize the four space–time derivatives of the scalar field S as the four components of the four current density $\boldsymbol{J}_{\square e}$:

$$\frac{1}{\mu_0}\boldsymbol{\partial} S = \frac{1}{\mu_0}\left(\gamma_x\frac{\partial S}{\partial x} + \gamma_y\frac{\partial S}{\partial y} + \gamma_z\frac{\partial S}{\partial z} + \gamma_t\frac{1}{c}\frac{\partial S}{\partial t}\right) = \boldsymbol{J}_{\square e}, \tag{8}$$

where $\boldsymbol{J}_{\square e} = \gamma_x J_{ex} + \gamma_y J_{ey} + \gamma_z J_{ez} - \gamma_t c\rho = \boldsymbol{J}_\triangle - \gamma_t c\rho = \rho\left(\boldsymbol{v} - \gamma_t c\right)$ is the four current density vector and $\boldsymbol{v}_\square = \gamma_x v_x + \gamma_y v_y + \gamma_z v_z - \gamma_t c = \boldsymbol{v} - \gamma_t c$ is the four velocity vector. The charge density is related to the time derivative of scalar field S

$$\frac{1}{c}\frac{\partial S}{\partial t} = \mu_0 J_{et} = -\mu_0 c\frac{\partial q}{\partial x \partial y \partial z} = -\mu_0 c\rho, \tag{9}$$

Using the seven component electromagnetic field $\boldsymbol{G}$, Maxwell's equations can be rewritten in the following compact form

$$\boldsymbol{\partial G} = \boldsymbol{\partial}^2\boldsymbol{A}_\square = 0. \tag{10}$$

$\boldsymbol{G}$ is a composition of a scalar and a bivector field and can be viewed as a spinor field in STA.

3. Electron *Zitterbewegung* Model

The concept of charge that emerges from the "Lorenz gauge free" Maxwell's equations [11], has a non trivial implication: the analysis of (9) shows that the time derivative of a field S which propagates at the speed of light, must necessarily represent charges that are also moving at the speed of light. Moreover, equation (10) is Lorentz invariant only for charges that move at the speed of light. This observation naturally suggests a pure electromagnetic model of elementary particles based on the ZBW interpretation of quantum mechanics [4,13]. The free electron can be viewed as a charge distribution that rotates at speed of light along a circumference with a length equal to electron Compton wavelength [14] as shown in Fig. 1. The charge may be seen as distributed on a spherical surface with a radius equal to electron classical radius $r_0 \simeq 2.817940 \times 10^{-15}$ m. The electron mass in natural units (NU) is equal to the angular frequency: $\omega_\mathrm{e} \simeq 5.11 \times 10^3$ eV (NU) or $\omega_\mathrm{e} \simeq 7.763440 \times 10^{20}$ rad/s (SI). This value is also equal to the inverse of

Table 2. Parameters of the *Zitterbewegung* model.

Item	Symbol	Value (SI)	Unit (SI)
Charge	e	$1.602176565 \times 10^{-19}$	C =A s
Zitterbewegung orbit radius	$r_\mathrm{e} = \lambda_\mathrm{c}/2\pi$	3.861593×10^{-13}	m
Intrinsic angular momentum	$\Omega = \hbar = h/2\pi$	$1.054571726 \times 10^{-34}$	J s
Spin[1]	$\hbar/2$	$0.527285863 \times 10^{-34}$	J s
Angular speed	ω_e	7.763440×10^{20}	rad s^{-1}
Mass	m_e	9.109384×10^{-31}	kg
Current	I_e	19.796331	A
Magnetic moment (Bohr magneton)	μ_B	9.274010×10^{-24}	A m^2
Vector potential	A	1.704509×10^{-3}	V s m^{-1}
Magnetic flux density	B_e	4.414004×10^{9}	V s m^{-2}
Magnetic flux	$\phi_\mathrm{e} = h/e$	4.135667×10^{-15}	V s
Magnetic energy	W_m	4.093553×10^{-14}	J
Electrostatic energy	W_e	4.093553×10^{-14}	J
Electron energy at rest	$W_\mathrm{tot} = m_\mathrm{e}c^2$	8.187106×10^{-14}	J
Charge radius	r_0	2.817940×10^{-15}	m
Inverse of the FSC	$\alpha^{-1} = r_\mathrm{e}/r_0$	137.035999	1
von Klitzing constant	$R_\mathrm{K} = h/e^2 = \mu_0 c/2\alpha$	25812.807	Ω

[1] Component of the angular momentum due to Larmor precession along an external magnetic field B_E.

ZBW orbit radius $r_\mathrm{e} = \lambda_\mathrm{c}/2\pi \simeq 1.956\,950 \times 10^{-6}\ \mathrm{eV}^{-1}$ (NU) or $r_\mathrm{e} \simeq 3.861593 \times 10^{-13}$ m (SI) and is equal to the reduced Compton wavelength:

$$\left(m_\mathrm{e} = \omega_\mathrm{e} = \frac{1}{r_\mathrm{e}} \approx 0.511 \times 10^6\ \mathrm{eV}\right)_\mathrm{NU},$$

$$m_\mathrm{e} = \frac{\hbar\omega_\mathrm{e}}{c^2} = \frac{\hbar}{c r_\mathrm{e}} \approx\ 9.109384 \times 10^{-31}\ \mathrm{kg}.$$

The angular momentum of the free electron according to the proposed model is

$$\Omega = eAr_\mathrm{e} = \hbar,$$

where e is the elementary charge and $A \simeq 1.704509 \times 10^{-3}\ \mathrm{V\,s\,m^{-1}}$ is the module of the vector potential $\mathbf{A}$ seen by the rotating charge. The value of the vector potential is determined by the current $I_\mathrm{e} = e\omega_\mathrm{e}/2\pi \simeq 19.796331$ A generated by the rotating charge. The angular momentum $\hbar$ of the free electron may explain the spin value $\hbar/2$ if we consider the electron interaction with an external magnetic flux density field $\boldsymbol{B}_\mathrm{E}$, as in the Stern–Gerlach experiment.

We can interpret the electron spin value $\pm\hbar/2$ as the component of the angular momentum vector $\boldsymbol{\Omega} = \hbar$ aligned with the external magnetic flux density field $\boldsymbol{B}_\mathrm{E}$. In this case the angle between the $\boldsymbol{B}_\mathrm{E}$ vector and the angular momentum has only two possible values, namely $\pi/3$ and $2\pi/3$ while the electron is subjected to Larmor precession.

All parameters that can be deduced from the electron ZBW model are resumed in Table 2, where the first three rows are referred to the model's input parameters. Thanks to the ZBW model it's possible to show a simple and intuitive explanation of the relativistic mass concept. The position in space–time of a charge that moves at the speed of light must be a light-like vector in every reference frame:

$$\lambda_\mathrm{c}^2 - c^2T^2 = 0, \tag{11}$$

where $T = \lambda_c/c$ is the ZBW period and λ_c the ZBW orbit length for an electron at rest. For an electron moving at constant speed v_z along the z axis orthogonal to the rotation plane, calling λ_v and T_v the new orbit length and the new ZBW period respectively, we can write

$$\lambda_v^2 + v_z^2 T^2 - c^2 T^2 = 0, \tag{12}$$

$$v_z^2 T^2 - c^2 T^2 = -c^2 T_v^2, \tag{13}$$

$$\lambda_v^2 - c^2 T_v^2 = 0. \tag{14}$$

Moreover, by substituting (11) into (12) we get

$$\lambda_v^2 = c^2 \frac{\lambda_c^2}{c^2} - v_z^2 \frac{\lambda_c^2}{c^2} = \lambda_c^2 \left(1 - \frac{v_z^2}{c^2}\right) \tag{15}$$

or

$$\lambda_v = \lambda_c \sqrt{1 - \frac{v_z^2}{c^2}}. \tag{16}$$

Finally, by considering that the mass is inversely proportional to λ_v and T_v, it is possible to write the relativistic expression of the mass as

$$m = \frac{m_e}{\sqrt{1 - \frac{v_z^2}{c^2}}}, \tag{17}$$

where m_e is the electron mass at rest. In Fig. 2 the helical space trajectory of the spinning charge of an electron subjected to an acceleration directed along the positive z axis is represented. Due to the acceleration the radius reduces itself according to (16).

This electron model may highlight some important connections and similarities between Maxwell's and Weyl equation.

By using STA the Dirac equation

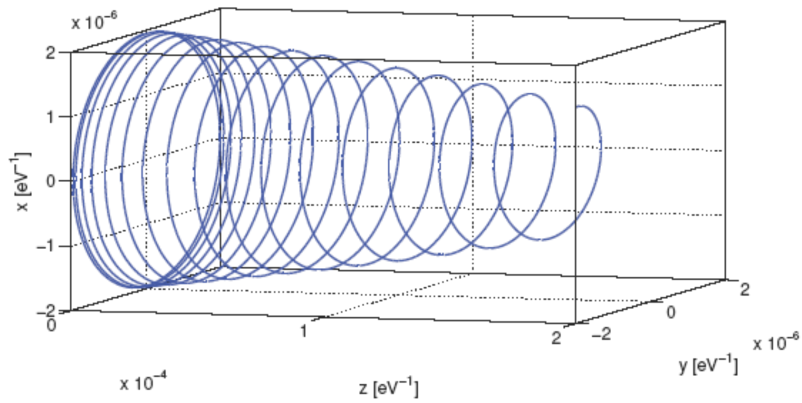

Figure 2. *Zitterbewegung* trajectory during an acceleration of the electron in the z-direction.

$$i\partial\!\!\!/\boldsymbol{\psi} - m\boldsymbol{\psi} = 0 \tag{18}$$

becomes the Hestenes–Dirac equation [15]

$$\boldsymbol{\partial\psi} - m\boldsymbol{\psi}\gamma_t\gamma_x\gamma_y = 0, \tag{19}$$

where $\boldsymbol{\partial}$ is an operator similar to the one used in Maxwell's equations $\boldsymbol{\partial G} = 0$ (see (4)), but using the space–time Minkowski signature of $Cl_{1,3}$ "$+ - - -$". For a massless particle $m = 0$ and (19) becomes the Weyl equation

$$\boldsymbol{\partial\psi} = 0. \tag{20}$$

Both equations (10) and (20) can be seen, from a mathematical point of view, as an extension in four dimensions of the Cauchy–Riemann conditions for analytic functions of a complex ("two-dimensional") variable [11,16]. The solution is always a *spinor* field. A spinor is a mathematical object that in Clifford algebra is simply a multivector with only even grade components. The movement of a point charge that rotates in the plane $\gamma_x\gamma_y$ and at same time moves up along the γ_z axis can be seen as the composition of an ordinary rotation in the plane $\gamma_x\gamma_y$ and a scaled hyperbolic rotation in the plane $\gamma_z\gamma_t$. These two rotations can be encoded with a single spinor of $Cl_{3,1}$.

The momentum $P_{\parallel}$ of the rotating charge is equal to the elementary charge times the vector potential generated by the ZBW current:

$$P_{\parallel} = eA_{\parallel} = \frac{\hbar}{r_{\mathrm{e}}} = \frac{\hbar\omega_{\mathrm{e}}}{c} = m_{\mathrm{e}}c.$$

An electron that moves with velocity $v \ll c$ along an axis orthogonal to the ZBW rotation plane has a momentum $P_{\perp}$ given by

$$P_{\perp} = eA_{\perp} \simeq P_{\parallel}\frac{v}{c} = m_{\mathrm{e}}v,$$

where $P_{\parallel}$ is the component of the momentum of rotating charge parallel to the ZBW rotation plane, $P_{\perp}$ is the orthogonal component and $A_{\parallel}$ and $A_{\perp}$ are the relative components of the vector potential seen by the spinning and moving charge. A variation of speed $a = \mathrm{d}v/\mathrm{d}t$ implies a force

$$f = \frac{\mathrm{d}P_{\perp}}{\mathrm{d}t} = e\frac{\mathrm{d}A_{\perp}}{\mathrm{d}t} = m\frac{\mathrm{d}v}{\mathrm{d}t}.$$

4. Electromagnetic Composite at Compton Scale

If the electron is a current loop (ring) whose circumference is equal to its Compton wavelength, it is reasonable to assume the possibility of existence of "super chemical" structures of picometric (1 pm = 10^{-12} m) dimensions.

A simple ZBW model of the proton consists in a current ring generated by an elementary positive charge that rotates at the speed of light along a circumference with a length equal to the proton Compton wavelength ($\approx 1.32141 \times 10^{-15}$ m). According to this model the proton is much smaller than an electron ($r_{\mathrm{e}}/r_{\mathrm{p}} = m_{\mathrm{p}}/m_{\mathrm{e}} \approx 1836.153$). A hypothetical very simple structure formed by a proton centered in the middle of the electron orbit would have a potential energy of $-e^2/r_{\mathrm{e}} \approx -3.728$ keV, corresponding to a photon wavelength of $\lambda_{\varphi} \approx 3.325 \times 10^{-10}$ m. This structure may be created only in presence of particular catalytic environments. A "resonant cavity" with dimensions comparable to

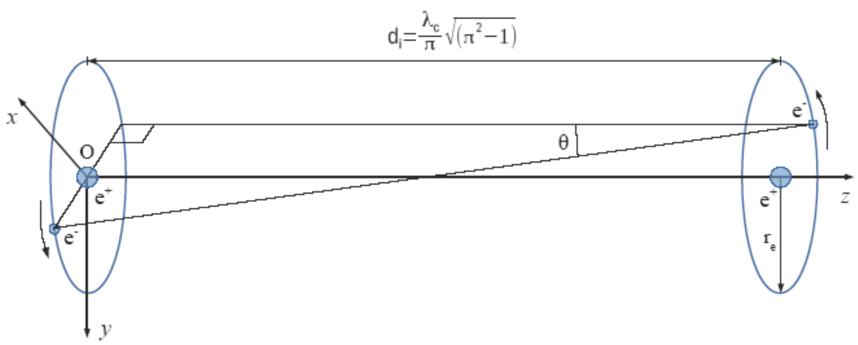

Figure 3. UDH protons distance.

$\lambda_\varphi = 332.5$ pm may facilitate the photon emission, acting as an "impedance matcher" with the external environment. Nickel has a lattice constant of 352.2 pm, a value not very far from λ_φ, and each Ni lattice cell may act as a resonant cavity and as an "energy emission catalyzer" in presence of Rydberg State Hydrogen, atomic hydrogen or hydrogen plasma, in systems very far from equilibrium. The generation of atomic hydrogen at relatively low temperatures may be catalyzed by nanostructured materials that catalyze the splitting of molecular hydrogen [17].

The hypothesis of existence of Compton-scale composites (CSC) has been experimental confirmed by prof. Holmlid [5]. The inter-nuclear distance in UDD of ≈ 2.3 pm, found by Holmlid, seems compatible with deuteron–electron (or proton–electron in UDH) structures where the ZBW phases of adjacent electrons are synchronized. Such distance may be obtained imposing, as a first step, the condition that the space–time distance $d_\square$ between adjacent electrons rotating charges is a light-like vector:

$$d_\square^2 = d_\vartriangle^2 - c^2\delta t^2 = 0,$$

where $d_\vartriangle$ is the ordinary Euclidean distance in 3D space. This condition is satisfied if $d_\vartriangle$ is equal to electron Compton wavelength ($d_\vartriangle = \lambda_\mathrm{c}$), $\delta t = T = \lambda_\mathrm{c}/c = 2\pi r_\mathrm{e}/c$ is the ZBW period and the phase difference between adjacent electrons is equal to π. In this case by applying the Pythagorean theorem we can find the internuclear deuteron distance d_i (see Figs. 3 and 4)

$$d_i = \frac{\lambda_\mathrm{c}}{\pi}\sqrt{\pi^2 - 1} \simeq 2.3001 \times 10^{-12}\ \ \mathrm{m}.$$

We must remark that the hypothesis of existence of exotic forms of "hydrogen" is not new and has been proposed in different ways by many authors (Mills [7], Dufour [9], Mayer and Reitz [8,18] and many others). An indirect support comes also from the numerous claims of observation of anomalous heat generation in Nickel–hydrogen systems.

Figure 4. UDH model.

These anomalies have been reported by many authors (Notoya, Mills, Piantelli, Mizuno, Hagelstein, Godes, Celani and others).

Mayer and Reitz, starting from a ZBW model of the electron, propose a three-body system model at the Compton scale, composed by a proton and two electrons. Prof. Piantelli in patent application WO 2012147045 "Method and apparatus for generating energy by nuclear reactions of hydrogen adsorbed by orbital capture on a nanocrystalline structure of a metal" proposes an orbital capture of "H- ions" by nickel atoms in nano-clusters as a trigger for Low Energy Nuclear Reactions [19]. The orbital capture of the negatively charged structures at pico-metric scale described by Mayer and Reitz may be viewed as an alternative explanation to the capture of the much larger H- ions.

Anomalous heat generation in Ni-H systems has also been reported by prof. Sergio Focardi and Andrea Rossi. Their impressive and revolutionary "energy catalyzer" (or "E-Cat") seems capable of reliable generation of thermal energy at kilowatt levels for many months! All these hypothetical "Compton Scale Composites" are electrical neutral or negatively charged objects that cannot be repelled by the Coulomb barrier and may generate unusual nuclear reactions and transmutations, considering the different sizes, time-scales and energies of this structures with respect to the particles (as neutrons) normally used in nuclear experiments.

5. Conclusions

Simplicity is an important and concrete value in scientific research. The application of Occam's razor principle to the Maxwell's equations suggests, as a natural choice, a ZBW interpretation of quantum mechanics. According to this framework, the electron structure consists of a massless charge that rotates at the speed of light along a circumference with a length equal to electron Compton wavelength. Following this interpretation, the electron mass-energy, expressed in natural units, is equal to the angular frequency of the ZBW rotation and to the inverse of orbit radius. The ZBW interpretation of quantum mechanics has been proposed as the best suited theoretical framework to understand the structure of ultra-dense deuterium and the origin of anomalous heat in metal–hydrogen systems and low energy nuclear reactions.

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