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Research Article

On Plausible Role of Classical Electromagnetic Theory and Submicroscopic Physics to understand and Enhance Low Energy Nuclear Reaction: A Preliminary Review

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Abstract

In this paper, we discussed how we can study some effects associated with LENR/CMNS from the principles of classical electromagnetic theory, and also from a very new approach based on a submicroscopic concept of physics. Perhaps our considerations have their own risks because the majority of mainstream physicists consider nuclear fusion rather as a phenomenon associated with tunneling through a Coulomb barrier, which is a pure quantum effect. We will discuss that there are some aspects of classical electromagnetic theories which may have impact on our understanding on LENR/CMNS phenomena, including: (a) nonlinear electrostatic potential as proposed by Eugen Andreev, (b) vortex sound theory of Tsutomu Kambe, (c) nonlinear ponderomotive force, and (d) submicroscopic consideration.

Keywords: Classical electromagnetic theory, Coulomb barrier suppression, Electronuclear potential, Nuclear Van der Waals force, Ponderomotive force, Subdeuterium, Submicroscopic physics, Vortex sound theory

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1. Introduction

Since Pons and Fleischmann reported their experiments in 1989, many labs in the world tried to replicate their results, but many failed. Thereafter, there was a wave of rejection to their claim of table-top nuclear fusion at room temperature. Some establishment physicists even called "cold fusion" *pathological science*. But many nonmainstream physicists and chemists continued their works in an underground manner. Also some eminent physicists have taken risks to join this underground movement, including Prof. Peter Hagelstein from MIT.

But the rejection of mainstream physics towards cold fusion/LENR remains strong. Even the famous Prof. Brian Josephson from Cavendish Lab. in Cambridge University was denied access from arXiv server because of his endorsement to E. Storms' works. He went on to write a paper suggesting that such a denial of many successful experiments related to cold fusion/LENR can be called "*pathological disbelief*."

In this context, allow us to recall a story that was told to the first author (VC) several times by Dr. Iwan Kurniawan, a nuclear engineer from Indonesia.[a] When he was a doctoral student in a University in Japan in the 1990s, his professor invited him to do an experiment related to cold fusion in the physics lab. After setting all the apparatus properly, they went home. In the morning, they were surprised that all the apparatus was blown up and it damaged the window glasses in lab. Dr. Iwan told me that since then he concluded that cold fusion does not work as claimed by Pons and Fleischmann.

He has been one of our good friends for a long time, and he and VC often discussed many things. But we have a different opinion regarding his cold fusion experiment: the fact that the apparatus blew the entire lab indicates that there was huge energy release in the device, so huge that it damaged the window glass. The problems appear to come from at least two aspects: (a) poorly understood mechanism of the reaction and (b) the reactor failed to work properly. So, it is basically similar to reactor meltdown in a usual fission reactor. We need to learn what makes their cold fusion reactor failed. It is not because there is no energy inside the system, but because there was a huge energy release. Reactor shutdown has recently been admitted as one of the real problems in many LENR reactors, and this is a challenge for experimenters and companies who want to design commercial LENR reactors [8–10].

However, in this paper we will not repeat such debates that have been discussed many times elsewhere. Instead we will discuss how we can study some effects associated with LENR from the principles of classical electromagnetic theory. We are aware that this approach has its own risks, because many physicists consider that nuclear fusion should be associated with tunneling through Coulomb barrier, and this kind of tunneling is a pure quantum effect. But is that true?

We will discuss the possibility there are some aspects of Classical electromagnetic theories which may have an impact on our understanding on LENR phenomena, including: (a) nonlinear electrostatic potential as proposed by Eugen Andreev, (b) vortex sound theory of Tsutomu Kambe, and (c) nonlinear ponderomotive force. The latter aspect has been proposed recently by Lundin and Lidgren in order to understand the mechanism of LENR [13,14].

It is our hope that this paper will motivate young electrical engineers to study LENR phenomena from new perspectives starting from classical electromagnetic theories. In short, classical electromagnetic theories still offer many surprises to those who are willing to dig deeper into the hidden mysteries of nature.

2. Nonlinear Electrostatic Potential of Eugen Andreev

In modern physics, there is a firm conviction based on the vast empirical material that:

- The electromagnetic and nuclear interactions are of a different nature.
- The field of electric charge (proton, electron) is spherically symmetric.

[a] Special thanks to Dr. Iwan Kurniawan for telling his first-hand experiment with cold fusion. Wishing you will recover soon, brother!

- The nucleon–nucleon forces depend on the direction.

In his paper, Andreev [1] suggested a hypothesis that the notion of the nuclear interaction could be interpreted as a nonlinear distribution of the electrostatic potential, which manifests itself on the Fermi scale. An analytical form of the potential of the proton is proposed, which coincides with conventional forms used in the nuclear physics at a short scale, but becomes the usual Coulomb potential at a large scale.

The model potential possesses a set of properties that could be called "*nuclear van der Waals forces*."

Coulomb's law can be written in integral form as follows [1].

$$\phi(x,y,z) = \frac{k\phi}{R} = -k \iiint_v \frac{\operatorname{div}(\nabla\phi(x,y,z))\mathrm{d}V}{\sqrt{(x^2+y^2+z^2)}}. \tag{1}$$

If we replace R with R_{dd}, which is defined as follows:

$$R_{\mathrm{dd}} = \sqrt{x^2+y^2+\beta^2 z^2+r_0^2}. \tag{2}$$

Then we will have a two parameter field potential [1]

$$\varphi(x,y,x,\beta,r_0) = \frac{\varphi}{R+r_0} \tag{3}$$

or

$$\varphi(x,y,z,\beta,r_0) = [\phi]\left(\frac{k_1}{R_{\mathrm{dd}}} + \frac{k_2}{\left|R_{\mathrm{dd}}\right|^2}\right). \tag{4}$$

In Andreev's approach, two new parameters were introduced, namely, a fundamental length of Heisenberg, r_0, which has to describe a discreteness of the physical vacuum and a parameter β depicting a deformability or polarizability of the physical vacuum. The conventional Coulomb's law appears from Andreev's expressions when $\beta = 1$ and $r_0 = 0$.

As a result, Andreev obtained an explicit analytic form of the *electronuclea*r potential of a proton [1]:

$$\varphi_{(\mathrm{proton})} = \frac{r_0}{\sqrt{(x^2+y^2+2z^2+r_0^2)}} + \frac{\mathrm{d}z\, r_0^2}{(x^2+y^2+2z^2+r_0^2)}. \tag{5}$$

Especially for one of the four orientations in a wide range of distances, the interaction energy Eq. (5) is negative, which indicates the existence of an *attractive* force and the possibility of forming a bound state [1]. Such behavior is similar to the van der Waals interaction (dipole–dipole, dipole-induced dipole, dipole–quadrupole interaction, etc.) which emerges between two nonbonded atoms and can be expressed as a function of internuclear separation, r.

This model includes a kind of anisotropy of space, represented by a coefficient "beta" in the direction Z of the nuclear spin, and includes also a parameter r_0 to eliminate the infinities in $r = 0$: r_0 would be the size of a discrete elementary cell of the physical (quantum) vacuum. This is very interesting, because in particular, it leads without preliminary hypothesis to retrieve the space partitioning into three areas, with a + sign for two external areas and a – sign for an internal one: that could represent the three quarks. Moreover, by computing the total energy of a proton-proton interaction, according to Andreev's potential model and as a function of various relative orientations of the proton, the author finds a mutual orientation providing an attractive interaction.

The above result, in fact, demonstrates the Coulomb barrier suppression starting from classical electromagnetics theory. Furthermore, Andreev has shown that PP potential as described above can be compared with [1]:

- Lennard–Jones potential (resulting from the van der Waals interaction):

$$V_{\mathrm{LJ}} = \frac{0.01}{r^{12}} - \frac{1}{r^5}. \tag{6}$$

- Reed potential

$$V_{\mathrm{Reed}} = -10\frac{\mathrm{e}^{-r}}{r} - 1650\frac{\mathrm{e}^{-4r}}{r} + 6484\frac{\mathrm{e}^{-7r}}{r}. \tag{7}$$

Thus the introduction of the discreteness of space (r_0) and its deformability (β) allows one to resolve the problem of overcoming the Coulomb barrier in nuclear physics.

Although this approach hints at a solution, much work still needs to be done, especially to establish how this model can be compared head-to-head with LENR/CMNS experiments. For more detailed information, the reader is advised to refer [1].

3. Vortex Sound Theory of Tsutomu Kambe [2–4]

The above-described electronuclear potential starts with electrostatics/Maxwell equations. It is very interesting to note that Prof. T. Kambe from University of Tokyo has made a connection between the equation of vortex sound and fluid Maxwell equations.

Kambe wrote that it would be no exaggeration to say that any vortex motion excites *acoustic* waves. Kambe considers the equation of vortex sound of the form [2] :

$$\frac{1}{c^2}\partial_{\mathrm{t}}^2 p - \nabla^2 p = \rho_0 \nabla \cdot L = \rho_0 \,\mathrm{div}(\omega \times v). \tag{8}$$

Also Kambe wrote that dipolar emission by the vortex–body interaction is [3]

$$p_{\mathrm{F}}(x,t) = -\frac{P_0}{4\pi c}\dot{\Pi}_i\left(t - \frac{x}{c}\right)\frac{x_{\mathrm{c}}}{x^2}. \tag{9}$$

Then he obtained an expression of fluid Maxwell equations as follows [4]:

$$\begin{aligned} &\nabla \cdot H = 0,\\ &\nabla \cdot E = q,\\ &\nabla \times E + \partial_{\mathrm{t}} H = 0,\\ &a_0^2 \nabla \times H - \partial_{\mathrm{t}} E = J, \end{aligned} \tag{10}$$

where [4] a_0 denotes the sound speed and

$$\begin{aligned} &q = -\partial_{\mathrm{t}}(\nabla \cdot v) - \nabla \hbar,\\ &J = \partial_{\mathrm{t}}^2 v + \nabla \partial_{\mathrm{t}} h + a_o^2 \nabla \times (\nabla \times v). \end{aligned} \tag{11}$$

In our opinion, this new expression of fluid Maxwell equations suggests that there is a deep connection between vortex sound and electromagnetic fields. Therefore, it may offer new ways to *alter* the form of electronuclear potential as described in Section 2.

However, it should be noted that the above expressions based on fluid dynamics need to be verified with experiments. We should note also that in Eqs. (10) and (11), the speed of sound a_0 is analogous of the speed of light in Maxwell equations, whereas in Eq. (8), the speed of sound is designated "c" (as analogous to the light speed in electromagnetic (EM) wave equation).

For octonic formulation of fluid Maxwell equations, see [15]. For alternative hydrodynamics expression of electromagnetic fields, see [16].

4. Nonlinear Ponderomotive Force

According to Brechet et al. [6], a ponderomotive force results from the response of inhomogeneous matter fields to the presence of electromagnetic fields. In particular, the Miller ponderomotive force could explain transmutations by thermal capture of neutrons in the context of the classical EM theory.

Ponderomotive forces are generally overlooked since the electromagnetic community is not much concerned with continuum mechanics, and the continuum mechanics community does not usually deal with electromagnetic systems.

The nonrelativistic ponderomotive force as proposed by Miller (1958) is as follows [7] :

$$F = m\bar{\bar{r}} = -\frac{q^2}{4m\omega^2}\nabla\left|\vec{E}(r,t)\right|^2. \tag{12}$$

Equation (12) can obviously be derived from the ponderomotive potential:

$$\varphi_{(\mathrm{p})}(r,t) = \frac{q^2}{4m\omega^2}\left|\vec{E}(r,t)\right|^2. \tag{13}$$

Other than Miller's force, there are other types of ponderomotive forces, i.e. [5] :

- Abraham force (1903),
- Barlow (1958),
- Lundin and Hultqvist (1989),
- Bolotovsky and Serov (2003).

It can be noted here that the Miller force is independent of wave frequency for $\omega^2 \ll \Omega^2$ and *attractive* for the entire frequency range below resonance. The Miller force is *repulsive* at frequencies above resonance, but decays strongly at higher frequencies. Ponderomotive forcing by electromagnetic waves is capable of causing the attraction of solid bodies.

Brechet et al. [6] discuss the electromagnetic force density of magnetoelectric ponderomotive force, which is different from Miller's force.

In a recent paper, Lundin and Lidgren proposed that Miller ponderomotive force may offer an explanation to nuclear spallation as observed in some LENR experiments [13]. Although their study is not yet conclusive, it opens an entirely new way to discuss LENR based on pure classical electromagnetic theory.

5. Submicroscopic Consideration

Monograph [11] presented a detailed structure of physical space (or a vacuum, ether), which is based on pure mathematical principles — set theory, topology and fractal geometry. The study shows that matter appears from a primary substrate that has a structure of a mathematical lattice named the *tessellattice.* Thus, all massive particles as well as electrically charged particles emerge from the tessellattice as local distortions of its cells. In this motion such anamorphosis has to interact with the *tessellattice*, which is neglected in quantum mechanical, quantum field and electromagnetic theories. The bulk fractal deformation of a cell of the tessellattice is associated with the notion of mass; it is thought that the surface deformation of a cell is related to the electric charge.

Hence, two kinds of equations should appear: one system of equations describes the behavior of a massive particle and one more system of equations depicts the behavior of the electric charge. The first system is quite new and presented in a book [11] and it is related to the quantum mechanical formalism; the other system is reduced to the conventional Maxwell equations, which is also illustrated in this book [11].

It has been demonstrated [11] that the interaction of a moving particle with the tessellattice results in the generation of a new kind of quasi-particles named *'inertons'*. These inertons are carriers of massive properties of particles and they play in some sense the role of hidden variables introduced in physics by de Broglie, Bohm and Vigier. Inertons exchange by mass, speed and hence momentum and kinetic energy with the particle that generates them. A section of space known as the particle's de Broglie wavelength λ is the spatial amplitude of the particle. It is a section in which the particle initially generates inertons and passing the whole kinetic energy to the generated cloud of inertons finally stops; then in the next section λ inertons guide the particle passing on to it their velocity, mass, momentum and kinetic energy.

The particle's inerton cloud together with the particle, which exist in real space, are projected to the quantum mechanical formalism, which was developed in a phase space, as the particle's wave ψ-function. Thus, in a solid each atom is surrounded with its inerton cloud; the same for each free electron, proton or another canonical particle.

In the recent experiment [12], in a chamber filled with a gas, a discharge has been generated. Positive ions of the gas reached the cathode where they interacted with atoms of an electrode made of tungsten. If the gas is hydrogen, discharges produce free protons in it. Reaching the cathode, protons interact with a metal matrix in such a way, that at the resonance conditions, i.e. when the momenta of the interacting atom and proton are coincide by absolute value and have opposite directions, i.e. the proton impacts the tungsten atom being in antiphase oscillating in its site of the crystal lattice, both particles must stop, $m_{\mathrm{p}}\vec{v}_{\mathrm{p}} + m_{\mathrm{W}}\vec{v}_{\mathrm{W}} = 0$. This condition means that the proton knocks out the tungsten's atom inerton cloud.

One of the free electrons available at the surface of the electrode absorbs the tungsten atom's inerton cloud and also traps a proton. The merging of the heavy electron with the proton results in the creation of a super heavy hydrogen atom. In this system the reduced mass of the proton and the electron is almost equal to m_{p} (indeed $1/m_{\mathrm{p}} + 1/(m_{\mathrm{e}} + m_{\mathrm{W}}) \simeq 1/m_{\mathrm{p}}$). Therefore, the proton starts to rotate around the heavy electron; the Bohr radius for the rotating proton is

$$r_{\mathrm{p-e}} = \frac{4\pi\varepsilon_0\hbar^2 n^2}{\mathrm{e}^2 m_{\mathrm{p}}} = 2.88 \times 10^{-14}\mathrm{m}, \tag{14}$$

where we put $n = 1$. Although the electron orbit (14) deeply penetrates into the middle of the proton, the electron still does not reach the critical distance of 2×10^{-14} m that characterizes the quark orbit inside the proton [11]. If we put $n = 2, 3$, the radius (14) will be larger but still in the order of femtometers.

What is interesting, these small atoms named subatoms [12] behave like neutrons, namely, neutron detectors measured the presence of neutrons in the experiment conducted. We [12] were able to generate subatoms, such as subhydrogen and subhelium (in a helium atmosphere), which were perceived by the neutron detector as real neutrons. The intensity of the measured "neutron" radiation was rather significant; the maximum value measured by the detector was 3×10^5 neutrons/cm^2 min. Nevertheless, the real intensity could even be five orders higher. Besides, analyzing our experiments, we came to the conclusion about the existence of other tiny systems: subdeuterium, neutral (deuteron + subhydrogen) pair, and neutral (deuteron + subhelium) pair.

Many other researchers reported similar very small stable atoms, or combined particles, though they were unable to explain their structure and properties.

All these nuclear systems had the size around several units of 10^{-14} nm. They can be generated artificially in a chamber filled with a gas. When a discharge is generated in the chamber, positive ions of the gas reaches the cathode where they interact with atoms of the electrode, which is typically made of tungsten.

When we launch the production of subatoms and the above mentioned nuclear pairs, at the high intensity of these entities we are able to anticipate the real transformation of nuclei in the system. Indeed, tiny subatoms and nuclear pairs (with the size $\leq 5 \times 10^{-14}$ m) can easily penetrate the shell of electrons around each atom, which have a size around 10^{-10} m. In other words, a subatom or nuclear pair moving to the nucleus of the atom will pierce the electron shell similarly to a spaceship that is travelling in our solar system. Any electron of the electron shell cannot experience this pinhole because of the incommensurability of the sizes of tiny particles and electron orbits.

Note that Andreev's phenomenological approach [1] to the suppression of the Coulomb barrier is consistent with the submicroscopic concept. Andreev points to some minimum size r_0. Indeed, scales of sizes of objects that compose the universal tessellattice prescribe an order of sizes of stable structures starting from the minimum, which is the size of the quark (in the lattice, the size is 10^{-10} or 10^{-17} m) and the size of an atom (in the lattice, the size is 10^{-17} or 10^{-21} m) [11]. Hence real space has to influence a physical mechanism of interaction. The tessellattice possesses an elasticity and Andreev's parameter β takes exactly this fact into account.

Approaching a nucleus, a subatom or nuclear part starts interacting with nuclides: a subatom brings to the nucleus a thermal proton (deuteron or α particle), the inerton cloud and electron. The electron will be getting away from the nucleus because it does not participate in nuclear reactions. But the proton (deuteron or α particle) will bring an additional interaction inside the nucleus, which has to result in its mutation.

In fact, studying samples of iron and samples of water contaminated with Cs-137 we [11] revealed significant mutations in iron (in which emerged such elements, as Co, Ni, Ca, Hf, Cs) and decrease in radioactivity of the water sample up to 30–40% at the application of an inerton field. It seems in those experiments initially subatoms formed that then influenced nuclei of Fe (in samples of iron) and nuclei of Cs-137 (in samples of water contaminated with radioactive cesium).

6. Discussion and Concluding Remarks

We have discussed a new expression of electronuclear potential starting from electrostatics law. This explains Coulomb barrier suppression from a purely classical origin, without the use of nuclear potential such as Woods–Saxon potential. The model potential possesses a set of properties that could be called "*nuclear van der Waals forces*." In our opinion, this is a quite surprising result that offers a novel way to explain low energy nuclear reaction (LENR) from Classical Electromagnetic theories.

Moreover, Kambe's new expression of fluid Maxwell equations suggests that there is a deep connection between vortex sound and electromagnetic fields. Therefore, this result may offer a new insight on how to *alter and modify* the form of electronuclear potential using vortex sound equations. This requires further investigations.

In a recent paper, Lundin and Lidgren proposed that Miller ponderomotive force might offer an explanation to nuclear spallation as observed in LENR experiments. Although their study is not yet conclusive, it opens an entirely new way to discuss LENR from purely classical electromagnetic theories.

The electrostatic/electronuclear potentials, fluid Maxwell equations and ponderomotive force have been proposed as an alternative to tunneling effects that could occur as a quantum mechanical consideration of LENR. However, in Section 5, we have shown that the tunneling effect itself can be considered in deeper terms, namely from the submicroscopic point of view. This is a quite new approach to the description of physical phenomena, which however, promises a lot in both our understanding of mysterious phenomena of nature and the modeling of some crucial experiments, such as LENR and similar work.

As follows from the submicroscopic concept, LENR can be possible only in the case when subatoms or nuclear pairs emerge in the system studied. An efficiency of LENR is directly proportional to the quantity of generated subatoms and nuclear pairs. That is why it seems possible that the highest efficiency in LENR can reached under the following two main conditions: (i) in a reaction chamber one has to increase the number of subatoms and nuclear pairs to the value of no less than 10^{12}; at this quantity of deuterons in a macroscopic sample reactions d + d = He produces heat comparative to room temperature; (ii) we need to invent mechanism(s) that would stimulate collisions of subatoms and nuclear pairs with potential targets and between themselves.

Of course, we do not pretend to have the last word on how to apply Classical Electromagnetic theory to understand LENR, instead we offer some new insights on how to explain and enhance the Coulomb barrier suppression without the usual quantum tunneling paradigm.

It is our hope that some of the proposed new theoretical approaches as described herein will be proved fruitful in the continuing study of CMNS/LENR.

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