DEEP-ORBIT-ELECTRON RADIATION EMISSION IN DECAY FROM $^4H^{*\#}$ TO ^4He

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Abstract **- The process of nuclear energy transfer to the lattice involves near-field electromagnetic coupling of energy from energetic charged nuclei to deep-Dirac level electrons. From there, the energetic electrons near-field and far-field couple energy into adjacent Pd-bound electrons causing intense local ionization, but no energetic radiation beyond the multi-keV level.**

Index Terms **– Deep-Dirac levels, Near-field coupling, Nuclear radiation, Relativistic radiators,**

I. INTRODUCTION

One of the major problems in the acceptance of Cold Fusion, CF, by the Nuclear Physics community is the lack of energetic particulate radiation known to occur in all deuterium-fusion reactions, D-D => $^4He^*$. This has been demonstrated by the present authors to be a 'sign-post' for a model proposed to show how CF can occur without release of energetic radiation [1]. The Lochon Model provided the pathway for deuterons in a palladium (Pd) lattice to overcome the Coulomb barrier that prevented all prior low-energy fusion reactions from occurring [2]. The natural extension of this model was able to identify the means of tunnelling beneath the fragmentation level to avoid the expected energetic particles [3]. The Extended-Lochon Model also provided a qualitative description of how the nuclear energy (~20 MeV) could be repeatedly transferred from the excited states of ^4He ($^4He^*$ and $^4He^{*\#\#}$, the excited state with lochon present) to the lattice without destroying it [4].

Fundamental to this development is the ability of one (or two) electrons to move deeply into the nuclear Coulomb potential and remain there long enough to allow protons to penetrate their mutual barrier. A theoretical basis, from the relativistic Dirac equations for actual orbits within fermis of the nucleus has been provided [5] and developed [6]. Fig. 1 provides a representative view of the near-nuclear region with energy plotted from the ^4He ground state.

The fuchsia curve (L=0) identifies the Coulomb barrier for the protons in a head-on collision (no angular momentum). The dashed line indicates the centrifugal barrier within the nuclear potential well (at ~0.4 fm) and the raising of an effective Coulomb barrier. For an even higher angular momentum (aqua curve), only a circular orbit is possible and a further increase in effective barrier is noted. Higher-energy orbits (e.g., n=1, green line) are not bound. The real potentials are not this clean since the neutrons, providing nuclear potential without Coulomb effects, are a major perturbation. The quantum mechanical wave function for a nucleon extends well beyond the 2-fm point and is not strongly affected by the shape of the potential well. The closely bound electrons, on the other hand, are able to follow the protons' motions and thus, over time, are spread well beyond the radius that we will use as an average for both the protons and deep-Dirac level electrons (R_p and R_{DDL} = 1 fm).

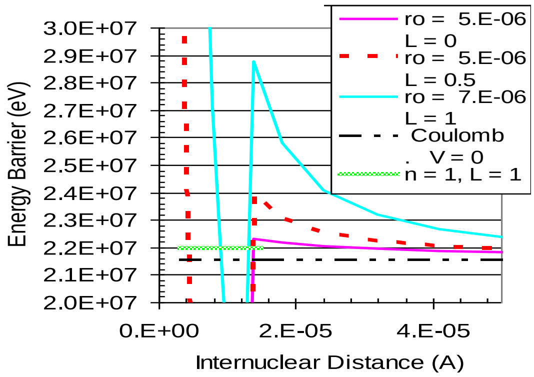

Fig. 1 The Coulomb and centrifugal-energy barriers for d-d collision (*l* = 0, 0.5, and 1). The solid curve, with the highest barrier, is for *l* =1.

The process of energy transfer involves the near-field electromagnetic coupling [7] of energy from the energetic charged nuclear dipoles to tightly confined (1 fm) electron dipoles (possibly in deep-Dirac levels, DDLs [5]. From there, the energetic electrons near-field-couple energy into the adjacent Pd-bound electrons and cause intense local ionization. Because of the ½ MeV binding energy of a DDL electron and its extreme proximity to the charged nucleus, significant radiant-energy transfer is possible, both into the DDL electrons and, from there, into the atomic electrons. However, since no resonances other than the Pd atomic-electron binding energies are obvious, no energetic radiation beyond their keV level is expected from this process. The steady loss of nucleon energy to the DDL electron(s), and their disturbing presence in the nuclear region, prevents the semi-stable nuclear orbits required for the formation of energetic gamma rays. This paper seeks to better describe and quantify the decay process and to identify the conditions and limits required to permit stable and efficient conversion processes from nuclear energy to thermal energy in the lattice via DDL electrons. In particular, it will describe the near-field EM coupling that will take place within the nuclear region of these 'femto-atoms'. While nucleon dipole coupling has been well studied [8], the coupling of nucleons to tightly-bound electrons and from there with nearby bound electrons may be new.

II. Near-Field Coupling: DDL Electrons to Atomic Orbital Electrons

Radiant nuclear energy transfer first involves near-field electromagnetic coupling of energy from the energetic charged nuclear dipoles to tightly-confined electron dipoles (in nought orbits or deep-Dirac levels [6]). These energized electrons subsequently near-field-couple energy into adjacent Pd-bound electrons, thereby causing intense local ionization. However, they produce little energetic radiation beyond the multi-keV level of the inner Pd electrons. This far-field photonic-radiation process is closer to what we may be familiar with, so we begin our analysis with the relativistic radiated-electric field (1)[1] of the DDL electrons at the Pd atomic electrons.

$$\boldsymbol{E}(\boldsymbol{x},t) = \mathrm{e}\left(\frac{\boldsymbol{n}-\boldsymbol{\beta}}{\gamma^2(1-\boldsymbol{\beta}\cdot\boldsymbol{n})^3R^2} + \frac{\boldsymbol{n}\times[(\boldsymbol{n}-\boldsymbol{\beta})\times\dot{\boldsymbol{\beta}}}{c\,\gamma^2(1-\boldsymbol{\beta}\cdot\boldsymbol{n})^3R}\right)_{ret}. \quad (1)$$

The $\boldsymbol{\beta}$ and $\dot{\boldsymbol{\beta}}$ (= $\boldsymbol{\beta}$ dot) terms, are the source velocity and acceleration, respectively, divided by the velocity of light, c. R is the distance between the source and 'test' or target positions and $\gamma = 1/\mathrm{sqrt}(1-v^2/c^2)$. All of this is at the 'retarded' time position, which does not enter into the present picture. An important part of (1) is the relative weight of the two terms from a common nuclear-proton source. The first is the electrostatic Coulomb field modified for relativistic velocities of the radiating charge. The second is the radiation field that depends on both relativistic velocity and charge acceleration (a = F/m).

Fig. 2 identifies three regions of electron resonance in the hydrogen atom. The atomic orbitals are known and accepted. The deep Dirac levels are predicted by the relativistic Schrodinger, the Klein-Gordon, and the Dirac equations. They have not been recognized yet, except within CMNS. They are in the region of nucleon motion and of halo nuclei.[2] The Compton resonance, related to the electron mass energy equivalence and wave nature, is not explicitly found in the Schrodinger formulation of quantum mechanics. Nevertheless, One of the present authors has suggested it as a resonance (to explain Zitterbewegung) and it is proposed and suggested in the literature [9].

The primary energy storage and exchange mechanisms discussed in this paper are those of the protons and DDL electrons in the nuclear region and the coupling between these levels and those of the atomic electrons. The Compton resonance is only suggested as a transition point between the collision-dominated and photonic-radiation-dominated energy-exchange regimes. Note the five orders of magnitude between the proton and DDL electron motion and dipole moments and those dimensions of the atomic and neighbouring electrons.

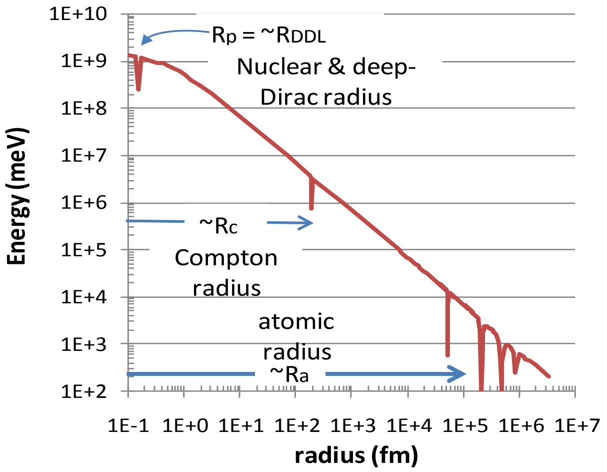

Fig. 2 The bound-electron energy levels for hydrogen as a function of radius from the center of force.

We will first compare the radiant **E** field of the atomic electrons relative to the proton and atomic-electron Coulomb fields at the bound atomic electrons. In (2), the ratio of the two terms eliminates the velocity effect and only leaves a comparison between the atomic electron's orbit radius and, strangely enough, its classical radius. At atomic distances;

$$\frac{\text{atomic Coulomb term}}{\text{atomic EM radiation term}} = \frac{1/R_a{}^2}{\dot{\boldsymbol{\beta}}/R_a c} = \frac{c}{R_a\,\mathrm{F}/mc} =$$

$$= \frac{mc^2}{R_a(e^2/R_a{}^2)} = \frac{R_a}{R_c} = \sim\frac{10^{-10}}{2.8x10^{-15}} = 3.5x10^4\,, \quad (2)$$

where R_c is the classical electron radius (e^2/mc^2 = ~2.8 fm) and R_a is the atomic electron orbital radius (~0.1nm). The latter is the radius for the acceleration term of the atomic electrons and a rough figure for the inter-electron distances. This indicates that the radiation **E**-field strength between atomic electrons is only a small fraction of the Coulomb field between the electrons or between the electrons and nucleus. How does the radiation field from the DDL electron at the atomic orbits compare with the Coulomb field from the proton?

Two differences between the DDL-electron and the proton or atomic-electron Coulomb and radiation fields in (1) are in the factors of γ and $\boldsymbol{\beta}$. For the relativistic DDL electron, they are 3 and 0.9 respectively, instead of 1. The relativistic contribution from these terms is to multiply the maximum Coulomb and radiation field by an order of magnitude. This comes from $(\boldsymbol{n}-\boldsymbol{\beta})/\gamma^2(1-\boldsymbol{\beta}\cdot\boldsymbol{n})^3$, where the maximum magnitudes give the particular relativistic correction $\mathcal{R}$ = ~ (1-0.9)/3^2(1-0.9)^3 = ~11.

Making a comparison of the Coulomb binding of an atomic electron relative to the maximum far-field

[1] http://en.wikipedia.org/wiki/Li%C3%A9nard%E2%80%93Wiechert_potential#Corresponding_values_of_electric_and_magnetic_fields
[2] http://en.wikipedia.org/wiki/Halo_nucleus

radiation (assume distance R_a = 0.1 nm) from the relativistic DDL electrons (for γ = 3 and relativistic correction $\mathcal{R}$ = 11), we get (3):

$$\frac{\text{proton Coulomb}}{\text{DDL EM farfield}} = \frac{1/{R_a}^2}{(\boldsymbol{n}-\boldsymbol{\beta})\dot{\boldsymbol{\beta}}_{DDL}/\gamma^2(1-\boldsymbol{\beta}\cdot\boldsymbol{n})^3 R_a c} =$$

$$\frac{\gamma m c^2}{\Re R_a (e^2/{R_{DDL}}^2)} = \frac{3R_{DDL}}{11 R_a R_c}^2 = \frac{\sim 0.27(10^{-15})^2}{10^{-10}\ 2.8x10^{-15}} = \sim 10^{-6}. \quad (3)$$

In this case, the DDL-electron radiated-field strengths are orders-of-magnitude larger than the atomic-electron, the nuclear Coulomb, or even the DDL-electron Coulomb fields. The distances from the DDL electrons and the deeper Pd-bound electrons of the adjacent Pd nuclei are not much different. The distances to the nearby lattice atoms are only factors of 2-4 greater. This could mean that, if screening were ignored, ionization could take place hundreds of lattice sites from a DDL electron. This is clearly not observed; so either DDL electrons do not exist (the standard response), the calculation is wrong, or something else interferes with the ionization process. Assuming the last, what can prevent total ionization near a DDL electron?

Actually, several things prevent total local ionization. First, the relative frequencies of the DDL and atomic electrons mean that the interaction probability is very high; but the ability to transfer energy is very low (as much energy is taken away as is added in each cycle). It is not possible to have the uncompensated ½ cycle (or portion thereof) required for net energy transfer. The relative frequencies ν are ~ 10^{16}/s for atomic electrons vs ~ 10^{22}/s, in (4), for DDL electrons.

$$\nu_{DDL} = \frac{0.9c}{2\pi r_{DDL}} = \frac{0.9 \text{ x } 3x10^8 \text{ m/s}}{3x10^{-14} \text{ m}} = \sim 10^{22}/\text{s}. \quad (4)$$

With six orders of magnitude difference in frequency, if the far-field radiation from the DDL electron gives the electron enough energy for ionization during one-half cycle, it takes it back during the next half. This is why an energetic gamma ray can go through matter with little ionization along its path. On the other hand, gamma rays *do* cause some ionization in matter. Therefore, an excited DDL electron, which produces the equivalent of a standing-wave gamma ray, can still cause ionization from interactions in the small volume about its femto-atom.

Since this frequency difference is a major limitation in the energy transfer to atomic electrons, it is worth exploring it further. Photons have a diameter of $\lambda/2\pi$; therefore, gamma rays, with wavelengths comparable to nuclear dimensions, have only small interaction with electrons in matter. DDL electron orbits are of similar dimensions. Therefore, only if an electron comes close enough to a femto-atom (within 10s of fm) for direct interaction (net fractional EM cycle) will significant energy transfers become possible. The differences between a gamma ray and the DDL electron near-field is that the gamma ray is transient, but it traces out a path through matter. The DDL field is long-lived, but has only a small interaction volume. However, since the atomic electron density gets higher as the femto-atom approaches a lattice nucleus, and more electrons means more energy exchange and more lowering of the excited femto-atom's energy, there is an attractive force (F = -dV/dr) that draws femto-atoms to nuclei.

The second reason that total ionization does not occur over large volumes is the screening effect of the bound and free electrons in the lattice. The calculated Debye length, which has been used in an attempt to allow penetration of the proton-proton Coulomb barrier for cold fusion, now becomes the factor that prevents massive disruption of large volumes in the lattice.

The third reason why the DDL electrons do not radiate all of their energy away and collapse into the nucleus is the same reason that the atomic ground states do not radiate away their energy and drop into the nucleus or into the DDLs. The answer is not the standard QM statement that the electron is at an energy minimum. The ground state is like all other orbitals; it is a minimal, a *local* minimum, not a general minimum. However, there is insufficient angular momentum in the ground state and below to create photons. A transition with 0 => 0 angular momentum transfer is highly forbidden.

What prevents a 2-p electron, which does have enough angular momentum to form a photon, from dropping to the DDLs? There are 3 reasons:

a) there is the 10^6-frequency difference between the DDLs and atomic orbitals mentioned earlier;
b) if there is a vacant s-orbital at closer to the same energy (frequency), the 2-p electron will go there, not to a DDL;
c) if there are no unfilled atomic orbitals below a p-electron, then the EM fields (standing waves) from the deeper atomic electrons prevent the higher-orbit electrons from losing energy.

Likewise, the DDL electrons are at a local minimum. However, because the Coulomb potential is no longer proportional to 1/r within the nucleus, because of the centrifugal barrier at small r, Fig.1, and because of relativistic effects, the DDLs may actually *be* at an energy minimum, not just a minimal point.

III. Near-Field Coupling: Protons to DDLs

Protons, being more massive than electrons, have much less acceleration when exposed to the same **E** field as an electron. This factor of 1800x is the reason that we can normally ignore radiation from protons. However, we know that nuclear protons in a compound nucleus can generate very energetic gamma rays. We also know that the deep nuclear potential well (for ^{4}He, V = ~80 MeV?) can cause great acceleration of the protons. And, while the exact shape of the potential well has little effect on the nucleon's wave functions, it does have an impact on the magnitude and type of radiation fields that it produces.

Going back to (1) for this new situation, we can do the same as we did for the atomic electrons. If we use the equivalent of (2) for a nuclear proton, assuming it to be bound by a Coulomb potential (for ease of calculation by similarity) with another proton in a ^{4}He nucleus, we obtain a ratio for the forces: This calculation holds for the protons' effect on a DDL electron also ($R_p = R_{DDL}$).

$$\frac{\text{p Coulomb}}{\text{p radiation}} = \frac{1/R_{DDL}{}^2}{\dot{\boldsymbol{\beta}}_{\boldsymbol{p}}/R_{DDL}\,c} = \frac{c}{R_{DDL}\text{ F}/mc} = \frac{m_p c^2}{R_{DDL}(e^2/\,R_p{}^2)}$$

$$= \frac{m_p R_p{}^2}{m_e R_{DLL}\ R_c} = \sim \frac{1800\,x10^{\ -15}}{2.8x10^{-15}} \ = = \sim 6x10^3. \quad (5)$$

The central attraction of the nuclear potential for the proton is again much greater than the maximum radiant fields that the proton can generate at its limited location relative to the center of attraction.

What effect does our assumption of a 1/r potential have on the calculation for maximum radiation field strength? It provides a lower limit for the term. The value used for the acceleration term in (5) assumed a circular orbit. If it were not circular, the maximum radiation would be at the minimum radius and that could be a fraction of the 1 fm used. However, it cannot be a small fraction since the repulsive nuclear 'hard-core' would prevent that. Assuming that $R_{min} = R_p/10$, the maximum Coulomb force would be only 70x the EM radiation force. However, this maximum EM field strength would be periodic, not continuous. Since the peak value is not sufficient to cause ionization of the DDL electron and the average value is unchanged, the new result is not different from the earlier estimate of the relative influences of Coulomb vs radiated fields.

What happens if a simple harmonic oscillator (SHO) potential is used instead of the Coulomb potential, i.e., $F_{SHO} = kr$ rather than $F_C = e^2/r^2$. The circular orbit, and average value of EM field strength, will be unchanged. However, the maximum value might be different. In the SHO case, the extreme is at large values of r. In the Coulomb case, the maximum acceleration occurs when the proton encounters the hard-core, or goes nearby. Only if the proton actually encounters the hard core is the acceleration significantly different between the two potentials

How does the proton's Coulomb field strength at the Pd-electron orbits compare with the Coulomb and EM-field strengths at and from the DDL electrons? The proton and electron Coulomb fields are similar in the DDL region. However, the electron has a contribution from its relativistic velocity that affects both the radiation field and its effective mass, $\boldsymbol{\mathfrak{R}} = 11$ and $\gamma = 3$. We will, consider the larger of the two Coulomb fields. If we do a similar exercise as in (5) above for the relativistic DDL electrons ($\gamma = 3$), $\boldsymbol{\mathfrak{R}}$ cancels out and we see (6):

$$\frac{\text{DDL Coulomb}}{\text{DDL near field}} = \frac{1/R_{DDL}{}^2}{\dot{\boldsymbol{\beta}}/R_{DDL}\,c} = \frac{c}{R_{DDL}\text{ F}/\gamma mc} =$$

$$\frac{\gamma mc^2}{R_{DDL}\,(e^2/R_{DDL}{}^2)} = \frac{3R_{DDL}}{R_c} = \frac{3x10^{-15}}{2.8x10^{-15}} = \sim 1. \quad (6)$$

In this case, the radiated-field strength of the DDL electron at the nucleus or at another DDL electron is of the same order-of-magnitude as its Coulomb field, and ~ 4x greater than the Coulomb field of a proton at the DDL. This could cause serious perturbation, or major resonances, if more than one DDL electron is present. However, the spin coupling – not included here - would likely dominate in this range.

IV. Relative field strengths: of Protons at DDL electrons vs that of DDLs at atomic electrons

This section addresses the relative field strengths radiated from excited nuclei and measured at DDL electrons to those radiated from excited DDL electrons and measured at atomic and free electrons in the vicinity. Even though the nuclear-proton radiated **E**-field strength at the deep-Dirac orbit $R_{DDL} = R_p$ is less than its Coulomb field strength there (5), it is still much greater than the radiant field of a DDL electron at an atomic electron's orbit R_a, (7).

$$\frac{\text{DDL far}-\text{field}}{\text{p near}-\text{field}} = \frac{\mathfrak{R}\,\dot{\boldsymbol{\beta}}_{DDL}/R_a c}{\dot{\boldsymbol{\beta}}_{\boldsymbol{p}}/R_{DDL}\,c} = \frac{\mathfrak{R}R_{DDL}}{R_a}\frac{m_p}{\gamma m_e}$$

$$= \frac{11R_{DDL}}{R_a}\frac{m_p}{\gamma m_e} = \frac{11x10^{\ -15}}{10^{\ -10}}600 = \sim 7x10^{\ -2}. \quad (7)$$

Therefore, the protons should be able to transfer energy more easily to the DDL electrons than the DDL electrons can to the Pd-bound electrons. However, if this is so, could the protons not also transfer energy directly to the atomic electrons, even if no DDL electrons were present? The ratio of DDL-electron to proton transfer to atomic electrons with $R_{DDL} = \sim R_p$ (8) indicates the large difference in effective EM-field strengths (6700x). Nevertheless, when compared with (3) the maximum proton radiant force is still ~130x greater than the Coulomb force holding the atomic electrons to the adjacent Pd nuclei.

$$\frac{\text{DDL far}-\text{field}}{\text{p far}-\text{field}} = \frac{\mathfrak{R}\dot{\boldsymbol{\beta}}_{DDL}/R_a c}{\dot{\boldsymbol{\beta}}_{\boldsymbol{p}}/R_a c} = \frac{11m_p}{\gamma\ m_e} = \sim 6700 \quad (8)$$

While the proton far-field forces are much less than those provided by the DDL electrons, the non-excited proton frequencies are much closer to those of the Pd electrons, particularly of the keV range inner electrons. Therefore, the excitation of atomic electrons by the proton radiation needs to be considered. Nevertheless, the large difference in energy levels for the inner electrons makes them less susceptible to excitation by the still higher-frequency proton radiation fields.

V. Decay Rates of $^4He^*$ to the Ground State

This section extends the last section where the field *strength* were considered and addresses the relative energy transfer *rates* from excited nuclei to DDL electrons as compared to those from excited DDL electrons to atomic and free electrons in the vicinity. If the energy transfer were dependent on field strength alone, then the near-field energy transfer from the protons to the DDL electrons would always be much faster than the electrons can transfer energy to the far-field bound Pd electrons. Therefore, the excited nuclei should deliver enough energy to the DDL electrons to eject them almost immediately despite their high binding energy (~500 keV). What prevents this from happening? How does energy actually transfer from the nuclear potential to the lattice? Why does it not happen with normal (unexcited) nuclei?

As energy is transferred from the excited protons to the DDL electrons, the electrons move out of their meta-stable orbit to higher levels within the Coulomb potential. As they rise in the potential well, their orbital radius, R_p in (7), also increases. Consequently, the ratio of proton to electron energy transfer changes. However, the dependence is not completely as might be expected.

The field strength at the excited DDL electrons from the protons depends on R_{DDL}^{-1}; but the field strength generated by the DDL electrons depends on R_{DDL}^{-2}. Furthermore, as the excited DDL electrons move out with the newly-added nuclear energy, they slow down and lose the relativistic component of their radiation field. This means that, as the DDL-electron increases its orbital radius, its radiation fields decrease faster than does the proton radiation field at that location.

The nuclear-proton radiated **E**-field strength at an expanded deep-Dirac orbit (e.g., $R_{DDL'} = 400R_p$) is still less than its Coulomb field at that point - substitute $R_{DDL'}$ for R_{DDL} in (5). It is also much greater at that point than is the radiant field from an excited DDL' electron measured at an atomic electron's orbit R_a, (9). Therefore, the EM field strengths from nuclear to $R_{DDL'}$ (p mid-field), *relative* to the DDL' fields at atomic distances (DDL' far-field), actually increases as the DDL electrons move out under the influence of the EM fields of excited proton(s). Thus, we must look beyond this simple algorithm to determine the actual energy-transfer rates.

$$\frac{\text{DDL}'\text{ far} - \text{field}}{\text{p mid} - \text{field}} = \frac{\dot{\boldsymbol{\beta}}_{DDL'}/R_a c}{\dot{\boldsymbol{\beta}}_{\boldsymbol{p}}/R_{DDL'} c} = \frac{{R_p}^2 R_{DDL'}}{{R_{DDL'}}^2 R_a}\frac{m_p}{m_e}$$

$$= \frac{R_p}{400R_a}\frac{m_p}{m_e} = \frac{\sim 10^{-15}}{4x10^{-8}}2000 = \sim 5x10^{-4}. \quad (9)$$

As an example, let us give the DLL electron sufficient energy to raise its orbit from R_{DDL} = ~1fm, with a binding energy of 507 keV, to $400R_{DDL}$, with a binding energy in the low keV range. Its initial kinetic energy of ~ 1 MeV is decreased to ~ 4 keV. Its initial potential energy of ~ 1.5 MeV is decreased to ~ 8 keV.[3] What has happened to this deep-orbit electron? It is still 'deep', just not as deep as it was initially.

As the DDL electron orbit grows with energy fed from the nuclear proton(s), its interaction volume grows too. In the example chosen ($R_{DDL'} = 400R_p$), the interaction volume with transiting bound electrons has increased by ~ $(400)^3 > 1x10^7$. This increase in interaction volume is the first step in the dissipation of excited-nuclear energy. Until, or unless, the femto-atoms drift close to a lattice atom, the primary source of collisions is with the numerous Pd d-orbital electrons. These are more likely to get within range of the DDL' electrons and have less binding energy. Therefore, they are the best means of transferring energy from the DDL' electrons.

As the excited DDL electron slows down and its orbital frequency decreases with expanding orbit with energy fed from the nuclear proton(s), it now has orbital frequencies closer to that of photons with the resonant energies of the Pd inner orbital electrons. It also has a dipole moment that has increased by two orders of magnitude. Both effects feed photonic energy emission.

A DDL electron has always had sufficient energy and field strength to ionize nearby atomic electrons; but now it has near-field resonant coupling and a larger dipole moment with which to work. The energy transfer between excited DDL electron and atomic electrons goes up by many orders of magnitude. The dominant transfer mechanism has changed from collision mode to photonic radiation mode. However, the latter is still dependent on the former. Only by collisions can the DDL' electrons obtain the angular momentum necessary for photon emission. On the other hand, it may be possible for double-photon emission from the intense EM fields to satisfy those requirements. However, it is not likely that this would be a major source of energy transfer.

The additional energy drain may still not be sufficient to keep up with the nuclear energy being fed to the excited DDL electron(s) – perhaps because the equilibrium population of the Pd inner electrons is depleted faster than they can be refilled. The excited DDL electron would then gain more energy from the excited proton(s), expand its orbit further, and slow it orbital velocity. It would thus be able to produce photons with lower frequencies. These lower frequencies are resonant with the much higher population of p- and even d-orbital Pd electrons.

If the process continues, with the stimulated DDL electrons getting pushed further from the $^4He^*$ nucleus, their orbital frequency decreases further and the photons generated are able to penetrate deeper into the local plasma being generated by the intense local ionization. This plasma actually reduces the Debye length and therefore the non-photonic EM field strength about the Femto-atom. However, at this point, the femto-atom may have been drawn close enough to a lattice nucleus to fuse with it. If fusion does not take place, and the DDL electrons approach their binding energy, then their frequency becomes equivalent to sub-eV plasma frequencies and yet another energy transfer mode becomes active in preventing these electrons from being lost from the femto-atom.

Since the strong EM fields convey information about the excitation state of the femto-atom and its nucleus, they also provide a basis for attraction and selectivity of radioactive nuclei relative to stable nuclei. A similar mechanism provides selectivity in the attraction of ground-state femto-atoms by radioactive nuclei [10]. This relative variation in the exchange of EM energy between bodies is a known variation on the Casimir effect.[4] Therefore, while the DDL electron provides a means for dissipating energy of excited nuclei, it also is the means of, and basis for selective, transmutation.

[3] These are back-of-the-envelope calculations, since there are no steady state values and calculations involve relativistic electrons. Values that are more accurate will have to be provided later.

[4] http://en.wikipedia.org/wiki/Casimir_effect#Analogies_and_the_dynamic_Casimir_effect

VI. More Representative Numbers

As an example of the desired quantitative results, consider the D+D => ^{4}He nuclear energy of ~20 MeV to be distributed into an average 5 eV Pd d-orbital electron ionization to the conduction band. This implies 4E6 ionizations. Assuming that the vacant d-orbital is refilled from the conduction band and adjacent d-orbitals within a picosecond and that there are, on average, four d-orbital electrons close enough for rapid energy transfer, then a decay time of ^{4}He*^ to ^{4}He of more than a microsecond would not cause any damage to the lattice. However, to attain the 'magic' number of 1E12 fusions per second, to produce a watt of thermal energy, this would require a steady level of 1E6 actively decaying ^{4}He$^{*\#\#}$ nuclei. If there were 1E14/cm^2 surface Pd atoms of material and only one in a million were part of a nuclear active environment (NAE) consisting of 100 Pd atoms, then the NAEs could be continuously productive at a rate of 1 W/cm^2 and still be at 1/10 the lattice-damage level.

VII. Summary

Bound-radiation field strengths are an important part of the ^{4}He* nuclear-energy transfer dynamics. The near-field radiation from the excited protons in a newly fused D-D pair is very strong at the deep-Dirac levels (DDLs). Only the ½ MeV binding energy of the electron(s) in these orbits keeps them from being immediately ejected. The far-field radiation from these relativistic DDL electrons is even stronger than that of the excited protons. However, the recipients of that energy, the atomic-orbital electrons, are generally orders of magnitude further away from the energy source than the DDL electrons and therefore less able to receive this energy. Thus, to first order, a nuclear proton can transfer energy to its DDL electron much faster than the electron can transfer it out to atomic orbital electrons. The major means of energy transfer from the DDL electrons in the early stages of ^{4}He* decay to ground state is by direct collision (near-field interaction) of atomic and DDL electrons.

With more energy coming from the protons than can be dissipated and by direct interactions with the transiting bound Pd electrons, the DDL electrons can pick up sufficient energy and angular momentum to radiate photons as well as producing bound EM fields. The very energetic electrons, with their expanding orbits and therefore larger dipole moments, can then radiate much greater average energy per unit time (photonically) than possible by direct collisions or off-resonant EM stimulation. Since the photonic emission rises rapidly as the DDL' electron orbit increases and orbital frequency approaches that of the numerous Pd-d electrons, it is unlikely that the femto-atom will eject their electron(s) without some abrupt change in the local system. Thus, a balance is established between the proton and DDL-electron, radiant-energy transfer. This is maintained until the protons get low enough into the ^{4}He potential well that resonant exchange between the protons and DDL' electrons overwhelms the electron binding energy and the DDL' electron(s) are ejected. This leaves the ^{4}He* atom in a slightly excited state from which proton radiation can bleed off energy into the Pd electrons to reach the stable ground state.

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