

Research Article

Deep-Orbit-Electron Radiation Emission in Decay from ${}^4\text{H}^{* \#}$ to ${}^4\text{He}$

A.Meulenberg*

Science for Humanity Trust Inc., Tucker, GA, USA

K.P. Sinha[†]

Indian Institute of Science, Bangalore 560012, India

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.

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1. Introduction

A major problem in the acceptance of Cold Fusion, CF, by the Nuclear Physics community is the widely accepted claim for CF in the PdD system to be nuclear. The most commonly proposed CF fusion reaction, $\text{D} - \text{D} \Rightarrow {}^4\text{He}^*$ but without energetic-particulate radiation, violates the well-known deuterium-fusion reactions. This apparent contradiction 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 proton fragmentation level (19.8 MeV above the ${}^4\text{He}$ ground state) 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 transferred from the excited ${}^4\text{He}^*$ (and ${}^4\text{He}^{* \#}$, the excited state with lochon present) to the lattice without destroying it [4]. This paper continues the development of the cold fusion models based on these assumptions by using dissipation of the nuclear energy via direct and EM radiation-coupling to the lattice. β

*E-mail: mules333@gmail.com

[†]E-mail: Kritpsinha@gmail.com

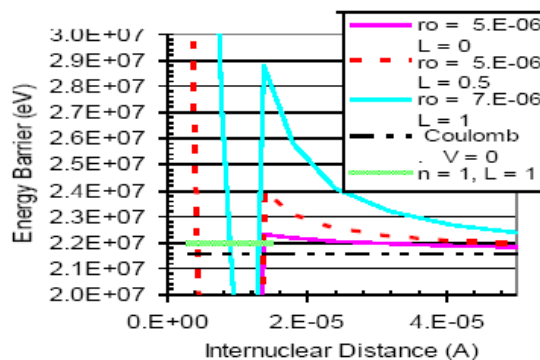


Figure 1. The Coulomb and centrifugal-energy barriers for d–d collision ($l = 0, 0.5$, and 1). The solid curve, with the highest barrier, is for $l = 1$.

Fundamental to these proposed models and their development is the ability of one (or two) electrons to move deeply into the nuclear Coulomb potential and remain there long enough to allow two protons (or deuterons) 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]. Figure 1 shows a representative view of the near-nuclear region with energy plotted from the ${}^4\text{He}$ ground state.

The fuchsia curve ($L = 0$) identifies the Coulomb barrier and nuclear potential well for two 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 through which the hydrogen must tunnel to reach the nuclear well.

For an even higher angular momentum (top, aqua, curve), only a near-circular orbit is possible and a further increase in effective barrier is noted. Higher-energy orbits are not bound. The real potentials for deuterium collisions 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 $R_{DDL} \approx 1$ fm).

Once non-resonant tunnelling^a has occurred in the proposed D–D fusion process and the excited state, ${}^4\text{He}^*$, is formed below the fragmentation levels (below 20 MeV, as proposed by the extended lochon model [3]), then the means of dissipating the excess nuclear energy and getting to the ${}^4\text{He}$ ground state must be considered. The initial process of energy transfer from the excited nucleus to the lattice 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 0.5 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 lack of any nuclear-energy levels below the proton fragmentation level, the steady loss of nucleon energy to the DDL electron(s), and their disturbing presence

^aThe reduced tunneling probability of non-resonant tunneling is compensated by the greatly reduced tunneling distance of the model.

in the nuclear region, prevent formation of any semi-stable nuclear orbits required for creation of energetic gamma rays. This paper seeks to better describe and quantify the proposed 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’ (a nucleus with an electron bound at the deep-Dirac level). While nucleon dipole coupling has been well studied [8], the coupling of nucleons with tightly bound electrons and from there with nearby lattice electrons may be new.

2. 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^b of the DDL electrons at the Pd atomic electrons.

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

The β and $\dot{\beta}$ ($= \beta$ dot) terms are the source velocity and acceleration, respectively, divided by the velocity of light, c . R is the distance along the unit vector n between the source and ‘test’ or target positions and $\gamma = 1/\sqrt{1 - v^2/c^2}$. All of these are at the ‘retarded’ time position, which does not enter into the present picture. An important part of Eq. (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 ($a = F/m$ or $\dot{\beta} = F/mc$). The radiation field, for our purposes is divided into the near-field (fields at approximately the same distance as the emitted wavelength) and the far-field (fields much greater than the emitted wavelength).

Figure 2 identifies three regions of electron resonance in the hydrogen atom. The atomic orbitals (radius in the angstrom range $= R_a$) are known and accepted. The deep-Dirac levels (radius in the low fermi range $= R_{DDL}$) 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.^d The Compton resonance (radius in the 380 fm range, but not discussed here), 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.

We will first compare the radiant $\mathbf{E}$ field of the non-relativistic ($\gamma = 1$) atomic electrons (second term of Eq. (1)) relative to the proton and atomic-electron Coulomb fields (first term of Eq. (1)) at the bound atomic electrons. In (2),

^bhttp://en.wikipedia.org/wiki/Li%C3%A9nard%E2%80%93Wiechert_potential#Corresponding_values_of_electric_and_magnetic_fields^c

^dhttp://en.wikipedia.org/wiki/Halo_nucleus

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;

$$\begin{aligned} \frac{\text{atomic Coulomb term}}{\text{atomic EM radiation term}} &= \frac{1/R_a^2}{\beta/R_a c} = \frac{c}{R_a F/mc} = \frac{mc^2}{R_a(e^2/R_a^2)} = \frac{R_a}{R_c} \\ &= \sim \frac{10^{-10}}{2.8 \times 10^{-15}} = 3.5 \times 10^4, \end{aligned} \quad (2)$$

where R_c is the classical electron radius ($R_c = e^2/m_e c^2 = \sim 2.8$ fm), F/mc is the atomic-electron acceleration from the Coulomb field, and R_a is the atomic-electron orbital radius (~ 0.1 nm). 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 Eq. (1) are in the factors of γ and β . For the relativistic DDL electron, they are 2–3 and ~ 0.9 , respectively. The relativistic contribution from these terms is to multiply the maximum Coulomb and radiation field by an order of magnitude. This comes from $(n - \beta)/\gamma^2(1 - \beta \cdot n)^3$ where the maximum magnitudes give the particular relativistic correction $\mathfrak{R} = \sim (1 - 0.9)/3^2(1 - 0.9)^3 = \sim 11$.

Making a comparison of the Coulomb binding of an atomic electron relative to the maximum far-field radiation (assume distance $R_a = 0.1$ nm) from the relativistic DDL electrons (for $\gamma = 3$ and relativistic correction $\mathfrak{R} = 11$), we get (3):

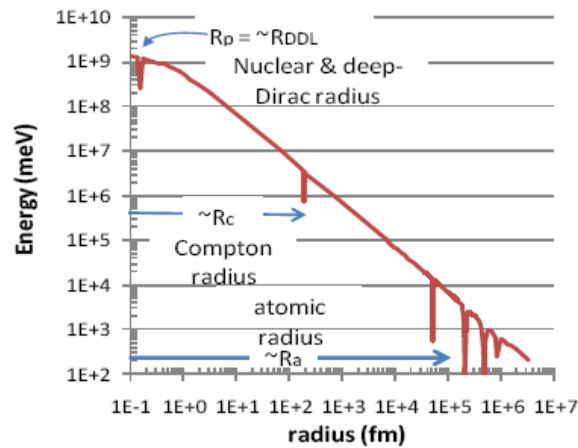


Figure 2. The bound-electron energy levels for hydrogen as a function of radius from the center of force.

$$\begin{aligned}
\frac{\text{Proton Coulomb}}{\text{DDL EM far-field}} &= \frac{1/R_a^2}{(n - \beta)\dot{\beta}_{\text{DDL}}/\gamma^2(1 - \beta \cdot n)^3 R_a c} = \frac{\gamma m c^2}{\Re R_a (e^2/R_{\text{DDL}}^2)} \\
&= \frac{R_{\text{DDL}}^2}{11 R_a R_c} = \frac{\sim 0.27(10^{-15})^2}{10^{-10} \times 2.8 \times 10^{-15}} \sim 10^{-6}.
\end{aligned} \tag{3}$$

In this case, the DDL-electron radiated-field strengths are orders-of-magnitude larger than that of the atomic-electron, the nuclear Coulomb, or even the DDL-electron Coulomb fields. The distances from the DDL electrons to the local atomic electrons and to 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, (3) indicates that 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 $1/2$ cycle (or portion thereof) required for net energy transfer. The relative frequencies ν are $\sim 10^{16}/\text{s}$ for atomic electrons vs. $\sim 10^{22}/\text{s}$, in (4), for DDL electrons.

$$\nu_{\text{DDL}} = \frac{0.9c}{2\pi r_{\text{DDL}}} = \frac{0.9 \times 3 \times 10^8 \text{ m/s}}{3 \times 10^{-14} \text{ m}} = \sim 10^{22}/\text{s}. \tag{4}$$

With 5–6 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 $\lambda/2\pi$ [10]; 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 $0 \Rightarrow 0$ 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 three reasons:

- (1) there is the 10^6 -frequency difference between the DDLs and atomic orbitals mentioned earlier;
- (2) 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;
- (3) 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.

3. 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 $\sim 1800\times$ 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 ${}^4\text{He}$, $V \approx 80$ 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 Coulomb binding of a DDL electron to, and the radiation from, a nuclear proton, assuming it to be bound by a $100\times$ Coulomb potential ($F_p = 100 \times F_{\text{DDL}}$, for ease of calculation by similarity) with another proton in a ${}^4\text{He}$ nucleus, we obtain a ratio for the forces. This calculated ratio for the protons' effects on a DDL electron using $R_p = R_{\text{DDL}} \approx R_c/3$ is

$$\begin{aligned} \frac{\text{p Coulomb}}{\text{p radiation}} &= \frac{1/R_{\text{DDL}}^2}{\dot{p}_p/R_p c} = \frac{c}{R_{\text{DDL}} F_p / m_p c} = \frac{m_p c^2}{R_{\text{DDL}} 100 F_{\text{DDL}}} \\ &= \frac{m_p c^2}{R_{\text{DDL}} (100 e^2 / R_p^2)} \approx \frac{m_p R_p}{300 m_e R_{\text{DDL}}} \approx 6. \end{aligned} \quad (5)$$

The central attraction of the nuclear potential for the proton, or the Coulomb attraction between the proton and DDL electrons, is again greater than the maximum radiant fields that the proton can generate at its limited location relative to the center of attraction. Thus the proton-generated EM-field at the DDL electron(s) will not be sufficient to overcome the Coulomb attraction by direct interaction. This provided another 'sanity check' for the DDL electron model.

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. The DDL electron would normally be in a near-circular orbit (perhaps as a rosette). Since it is tightly bound to a proton, it can transit a compound nucleus and perhaps even penetrate deeply into a proton. Radiation under these circumstances gets complicated. The result of (5) is large enough that the order-of-magnitude variations in the various near-nuclear R 's will not alter the conclusion of Coulomb forces greatly exceeding the proton radiation forces.

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, $\Re = 11$ 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 ($\gamma = 3$), $\Re$ cancels out and we see (6):

$$\begin{aligned} \frac{\text{DDL Coulomb}}{\text{DDL near field}} &= \frac{1/R_{\text{DDL}}^2}{\dot{\beta}/R_{\text{DDL}}c} = \frac{c}{R_{\text{DDL}}F_{\text{DDL}}/\gamma mc} = \frac{\gamma mc^2}{R_{\text{DDL}}(e^2/R_{\text{DDL}}^2)} = \frac{\sim 3R_{\text{DDL}}}{R_c} \\ &= \frac{\sim 3 \times 10^{-15}}{2.8 \times 10^{-15}} \approx 1. \end{aligned} \quad (6)$$

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

4. 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. This provides a basis for determining the flow of excited-nucleus energies into the lattice.

Even though the nuclear-proton radiated $\mathbf{E}$ -field strength at the deep-Dirac orbit $R_{\text{DDL}} = R_p$ is less than its Coulomb field strength there (5), it is still much greater at the near field than the radiant field of a DDL electron at an atomic electron's orbit R_a (7).

$$\begin{aligned} \frac{\text{DDL far-field}}{\text{p near-field}} &= \frac{\dot{\beta}_{\text{DDL}}/R_a c}{\dot{\beta}_p/R_{\text{DDL}}c} = \frac{\Re R_{\text{DDL}}m_p}{R_a \gamma m_e} = \frac{11 R_{\text{DDL}}m_p}{R_a \gamma m_e} \\ &= \frac{11 \times 10^{-15}}{10^{-10}} 600 \approx 7 \times 10^{-2}. \end{aligned} \quad (7)$$

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 large ratio of DDL-electron to proton energy transfer to atomic electrons with $R_{\text{DDL}} = \sim R_p$, (8) is indicated by the large difference in effective EM-field strengths ($6700\times$).

$$\frac{\text{DDL far-field}}{\text{p far-field}} = \frac{\Re \dot{\beta}_{\text{DDL}}/R_a c}{\dot{\beta}_p/R_a c} = \frac{11m_p}{\gamma m_e} \approx 6700. \quad (8)$$

Nevertheless, when compared with (3) the maximum proton radiant force is still $\sim 130\times$ greater than the Coulomb force holding the atomic electrons to the adjacent Pd nuclei. Why does not the radiant $\mathbf{E}$ -field eject all the local atomic electrons? The reason is that, because of the extremely high nuclear frequencies relative to the electron orbital frequencies, the electrons are pulled back into their original orbit (or lower) before they can escape. The net force of a very high-frequency field on a bound electron is zero. Only if the DDL $\mathbf{E}$ -field is instantaneously in proper phase with an atomic s-orbit electron, so that it can move the atomic electron during its transit of the nuclear region, can net energy be directly transferred from a DDL electron to an atomic-orbit electron.

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 still 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.

5. Decay Rates of $^4\text{He}^*$ to the Ground State

This section extends the last section where the field *strengths* 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, as seen in (1), the dependence is not entirely as might be expected.

The field strength at the excited DDL electrons from the protons depends on the distance between charges (R_{DDL}^{-1}); but the field strength generated by the DDL electrons depends on their acceleration, $a = F_{\text{DDL}}/m = e^2/R_{\text{DDL}}^2/m$, hence the orbital radius squared (so 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, $\beta = 11$, 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., $R_{\text{DDL}*} \approx 400R_p$) is still less than its Coulomb field at that point – substitute $R_{\text{DDL}*}$ 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 ratio of EM field strengths from nuclear-to- $R_{\text{DDL}*}$ (p mid-field) to the DDL* radiant fields at atomic distances (in the 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.

$$\begin{aligned} \frac{\text{DDL* far-field}}{\text{p mid-field}} &= \frac{\dot{\beta}_{\text{DDL}*}/R_a c}{\dot{\beta}_p/R_{\text{DDL}*}c} = \frac{R_p^2 R_{\text{DDL}*} m_p}{R_{\text{DDL}*}^2 R_a m_e} = \frac{R_p m_p}{400 R_a m_e} \\ &= \frac{\sim 10^{-15}}{4 \times 10^{-8}} 2000 \approx 5 \times 10^{-4}. \end{aligned} \quad (9)$$

As an example, let us give the DDL electron sufficient energy to raise its orbit from $R_{\text{DDL}} \approx 1$ fm, with a binding energy of 507 keV, to $400R_{\text{DDL}}$, 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.^e 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 ($R_{\text{DDL}*} = 400R_p$), the interaction volume with transiting bound electrons has increased by $\sim (400)^3 > 1 \times 10^7$. This increase in interaction volume is the first step in the dissipation of excited-nuclear energy. Until, or

^eThese 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.

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 a DDL* electron to the lattice.

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 may have increased by two orders of magnitude and, since the photo-transition probability increases with the square of the dipole moment [11], both effects greatly feed photonic energy coupling between the DDL electrons and the lattice electrons.

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 may go 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 its 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 of the $n = 2$ and 3 orbits.

If the process continues, with the stimulated DDL electrons getting pushed further from the ${}^4\text{He}^*$ 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. At some point in this process, the DDL electron frequency will drop below that of the excited nucleons and the rate of energy transfer between them will decrease greatly. Energy transfer between the excited nucleus and the lattice will now be limited by the emission rate of the DDL electrons and that, in turn, will depend on the DDL electron(s) acquiring sufficient angular momentum to form photons.

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 [12]. This relative variation in the exchange of EM energy between bodies is a known variation on the Casimir effect.^f 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.

6. More Representative Numbers

As an example of the desired quantitative results, consider the $\text{D} + \text{D} \Rightarrow {}^4\text{He}$ nuclear energy of ~ 24 MeV to be distributed into an average 5 eV Pd d-orbital electron ionization to the conduction band. This implies $\sim 5\text{E}6$ 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 ${}^4\text{He}^*$ to ${}^4\text{He}$ of more than a microsecond would not cause any damage to the lattice. However, to attain the ‘magic’ number of 1×10^{-12} fusions per second, to produce a watt of thermal energy, this would require a steady level of 1×10^6 actively decaying ${}^4\text{He}^{***}$ nuclei. If there were $1 \times 10^{14}/\text{cm}^2$ surface Pd atoms of material and only one in a million were part of a nuclear

^f http://en.wikipedia.org/wiki/Casimir_effect#Analogies_and_the_dynamic_Casimir_effect^g

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.

7. Summary

Bound-radiation field strengths are an important part of the $^4\text{He}^*$ 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 0.5 MeV binding energy of the electron(s) and the difference in frequencies between the DDL electrons and excited nucleons keep them from being immediately ejected. The far-field radiation from these relativistic DDL electrons is much stronger than that from the excited protons. However, the recipients of those energies, the atomic-orbital electrons, are generally orders of magnitude further away from these energy sources than are 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 $^4\text{He}^*$ decay to ground state is by direct collision (near-field interaction) or instantaneous phase coupling 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 (photonic) 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 ^4He 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 $^4\text{He}^*$ 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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