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Research Article

Radiation Coupling: Nuclear Protons to Deep-Orbit-Electrons, then to the Lattice

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Abstract

This paper [1] explores the properties of the tightly bound electrons predicted by the anomalous solution to the Dirac equations. Starting with the assumption that electrons can exist in these deep-Dirac levels (DDLs) with orbits in the femtometer range and ∼ 500 keV binding energies, the electromagnetic radiation fields and their coupling to both nuclear and atomic-electrons are identified. The shapes of both the nuclear potentials and the potential at the bottom of the Coulomb regime have a major role in the coupling between excited nucleons and the DDL electrons. The many orders-of-magnitude differences in frequency of the nucleons, the DDL electrons, and the atomic electrons account for the small interactions under normal circumstances. The changes in these frequencies in radioactive nuclides and for excitation of the DDL electrons account for many of the observed phenomena in cold fusion.

Keywords: Cold fusion, Deep-Dirac levels, Non-photonic coupling, Nucleon radiation, Potential shapes

1. Overview

The process of nuclear energy transfer from excited nuclei to the outside world is commonly by way of gamma radiation, particle emission, and neutrino emission. All processes require conservation of energy and angular momentum. The various decay paths are generally competitive and depend on the 'state' of the excited nucleus. This paper [1] will look at a non-standard process of nuclear-energy coupling to the lattice via the deep-Dirac level (DDL) electrons proposed as a primary pathway [2] in at least one decay mode of low-energy nuclear reaction: that of deuteron fusion, D–D to $^4He^*$.

The existence of [3] and processes of populating [4–7] these DDLs have been addressed in earlier papers. In this paper, we will assume that they exist (perhaps short-lived in the normal sense, e.g. femto-seconds) and that they can exist about an excited nucleus. In our energy-transfer process, without particle decay, nuclear-energy coupling to the lattice involves near-field (less than a wavelength) electromagnetic EM coupling of energy from energetic charged nuclei to deep-Dirac level electrons. From there, the energetic electrons couple energy (via near-field and far-field radiation) into adjacent free and bound electrons in the lattice. This coupling causes intense local ionization and perhaps energetic

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(multi-keV) electrons, but little or none of the energetic EM radiation normally observed from excited nuclei. There will be soft X-radiation from bound and free electrons decaying back into the emptied orbits of the lattice atoms. The resulting decays of the ionized and highly destabilized lattice atoms produce a greatly 'broadened' spectrum of photonic radiation with energies up to the binding energies of those electrons (eV to multi-keV level).

The ratios of the various energy transfer modes, nuclear to DDL, nuclear to lattice, and DDL to lattice have been explored in an earlier paper in terms of Maxwell's equations for the **E**-field strengths produced by the acceleration of the various charges involved [8]. This paper will spend more time on the coupling between the charges and therefore on the energy-transfer nature and probabilities. Many details, such as magnetic coupling and the differences between protons and neutrons within the nucleus, are not included here.

2. Radiation

2.1. Maxwellian

The 'Bible' for electromagnetic (EM) radiation studies is Maxwell's equations. However, Maxwell did not believe in photons and he certainly did not know about atomic-electron orbitals. Nevertheless, his equations hold up today, nearly a century and a half after he proposed them. They are continuing to be used (and misused) today. Their far-field component has been used to explain photons. But then quantum mechanics claim that only QM can explain why they stop radiating and why matter does not collapse as all bound electrons spiral into their nuclei. There are better reasons (see below [9]); but Maxwell's equations and the concept of non-photonic bound-radiation fields are fundamental to the development explored herein.

2.2. Atomic

Transitions between atomic-electron orbitals are the source of most of our observed light radiation. QM describes the basis for discreet orbitals as the mechanical resonance of an electron in a Coulomb potential well. It does not include

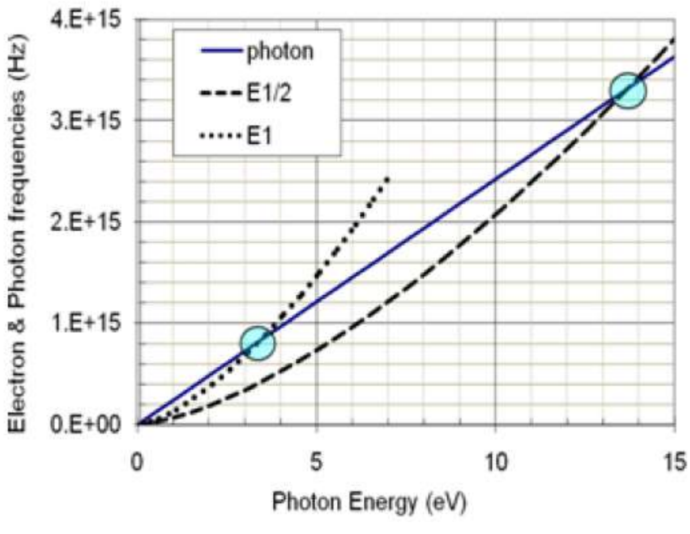

Figure 1. Relationship between hydrogen–electron and generated-photon frequencies and energies.

the EM radiation in those calculations. It simply states that the radiation matches the differences in the predicted energy levels and therefore the QM calculations are correct. They *are* correct, but they do not explain the mechanism of EM radiation caused by the 'fall' from one orbit into one deeper in the potential. Maxwell says that charge has an associated electric vector field, **E**. A uniformly moving charge also has a magnetic vector field, **B**. A cyclically moving charge has an EM field. He never mentioned the fields leaving. All of these fields are bound to the charge and cannot leave accept under special circumstances.

What are the special circumstances for radiation to occur from an atomic electron? Fig. 1, for a hydrogen atom, indicates the relationship between photon frequency E_γ and the electron orbital frequency (ν_e) that is proportional to $E^{3/2}$ [9]. The photon curve indicates the linear relationship between the photon frequency and its energy ($E_\gamma = h\nu_\gamma$). The E1 curve represents the electron frequency that corresponds to the photon energy at that frequency. Note that the resonance point ($\nu_e = \nu_\gamma$) is at $\sim$ 3.3 eV, which corresponds to the $n = 2$ level of H at $\sim$ 3.34 eV. The $n = 1$ ground state (13.6 eV) is identified by resonance with the $E_{1/2}$ curve. This curve represents one-half the frequency associated with the electron orbit [9]. Of importance here is the special frequency relationship between the electron and the photon that permits a photon to form about, and depart from, the atom.

The departure of a photon does not eliminate the bound EM-field. It is constantly being generated, even when an electron is in the ground state. The EM-field is part of the electron and contributes to the effective mass that must be used to calculate its kinetic energy [10]. This EM-field is confined as an evanescent wave; it can be considered to be a virtual photon [11]. What keeps the electron in the ground state from emitting a photon? QM says that the electron is at an energy minimum and cannot lose any more energy. Yet we know that an electron at 1 fm from a proton charge center has energy in the MeV range. So the atomic ground state is not a minimum energy. It is a local minimum, a resonance, as are all of the orbitals. The real reason is that it takes angular momentum of h to form a photon and the ground state electron does not have that amount to donate. Even if it did have sufficient angular momentum, the frequency mismatch between the electron and forming photon would prevent formation of the required resonant EM state called a photon.

2.3. Nuclear

Transitions between nuclear levels are similar to those of the atomic electrons and produce gamma rays. In this case, the charge oscillators are the nuclear protons and not an electron. While protons do not radiate as efficiently as electrons (when in the same accelerating field), a proton in a MeV field could radiate more than will an electron in a multi-eV field. There are major differences though [8]. While the nuclear frequencies and accelerations are much higher than those of the atomic electrons, the dipole moment is 4–5 orders of magnitude smaller. Other important differences are explored in the section on potentials.

2.4. Bound vs. unbound radiation

Decay transitions between energy levels require a release of energy from the local system. Both before and after the transition, the bound radiation field about the bound electron/proton pair is present. This is also true for the nuclear protons. Maxwell's equations (and their extension) give values to the bound **E**-field strengths resulting from the charge acceleration [8]. These EM fields are radiated out from the dipole-charge center, but are not released. They are evanescent waves that do not convey energy unless there is an absorber present. They are 'standing' waves with as much energy entering the dipole source as leaving. These evanescent waves 'reach out' and can interact with charges in the vicinity. Since, unexcited atoms are conservative systems, these interactions are reversible. If a photon can form and depart or be absorbed, this is an irreversible process. (It is reversible by the inverse operation with an incident photon.) However, there are other irreversible processes that a do not involve photons. These involve the bound EM waves in a direct energy-exchange process. We will discuss both processes below.

3. Radiation Coupling

3.1. Resonance

Energy exchange is almost always a resonance phenomenon. We will describe it in our system from a classical viewpoint of coupled oscillators. Two coupled oscillators, with different resonant frequencies, ν_1 and υ_2 will generate additional frequencies that depend on both resonants (e.g., $\nu_1 \pm \nu_2$). The process of finding the 'common' frequency classically is to establish the system of linear equations for both oscillators and then, after putting it into a matrix, to diagonalize the matrix. This is the basis of the Heisenberg matrix mechanics. And, since it has been proven that the Heisenberg formulation is equivalent to the Schrodinger wave formulation and thus QM, we will stick to the more-intuitive classical oscillator model for the present.

Consider a system consisting of the electron and its EM field. Since energy transfer is more efficient when the two oscillators are resonant (and both are resonant with the common frequency), we can see the resonant condition for photon formation, $1/(E_1 - E_2)$ comes directly from this condition, $1/(\nu_1 - \nu_2)$. Recognize that $1/(E_1 - E_2) = 1/(h\nu_1 - h\nu_2)$ is not valid in general. However, in a Coulomb potential, the kinetic energy KE of a non-relativistic orbital electron is equal to the photon energy E_γ that was released in the formation of the orbit by bringing the electron from infinity. Thus, $\mathrm{KE} = E_\gamma = h\nu_\gamma$ and this is also the binding energy BE of that energy level. The equality, $1/(E_1 - E_2) = 1/(\nu_1 - h\nu_2)$, is a nice way of keeping track of both the energy relationships and resonances. It ties the electron-energy levels to the photon release that can create the deeper orbits.

The derivation for the Bohr orbits, using classical resonance relationships between the electron and photon frequencies [9], speaks of a 'nascent' photon. This is the EM field that is approaching both the energy and frequency conditions for the photon that might be emitted. While the description identifies the conditions for both absorption and emission of photons, it does not emphasize the fact that the photon is an energy 'coupler' between the electrons of two atoms.

3.2. Couplers

In the simplest picture, consider an electron far from a proton. If bound to the proton, its orbital frequency and generated EM field is very low. As an oscillator, coupled to its EM field that is another oscillator, the electron can move its orbit closer to the proton by transferring energy to the field (if a photon can escape). In the process, it will increase its orbital frequency and its EM-field energy and frequency. If no photon is released, as in the inward portion of a non-radiating elliptical orbit, the EM field grows but then returns energy to the electron as it moves back out to its original position. Just as observed in coupled simple-harmonic oscillators that only change their amplitudes over time (at the common coupled frequency), the electron and EM field change their amplitudes; but, in a Coulomb potential, they also vary their frequencies over time. Since the photon has a single frequency for a given energy, but an infinite possible set of energies, its formation must depend on resonances with the electron. At these resonant frequencies, energy can be transferred quickly enough to allow a photon to 'complete' itself, become an independent soliton [12], and leave. During the emission process, there are three coupled resonators involved: the electron, its bound EM field, and the photon. This is an important factor that needs to be further explored.

The reverse process, photo-absorption, again depends on the resonance between the incident photon and the bound electron (and its EM field). In this case, the photon interacts with the electron by 'loading' energy into the electron's EM field. With a greatly enhanced EM field, the balance between the oscillators (EM field and bound electron) is shifted and the electron has its radius increased. Thus, it slows down and decreases its orbital frequency.

Unlike a simple harmonic oscillator that keeps the same frequency independent of the energy input, an electron in a Coulomb potential experiences changes in both its orbital and its EM-field frequencies. These changes are reflected in the anomalous dispersion relationship (Fig. 2) for resonant frequencies at the macroscopic levels. At the atomic level, the variations in the dispersion relationship are more extreme. The importance of resonance between the electron's

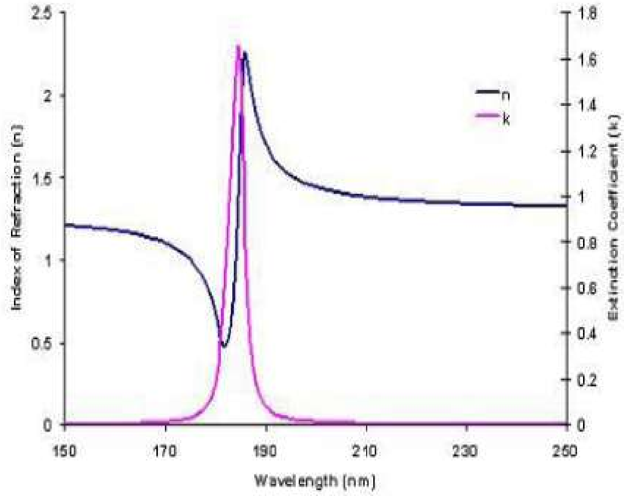

Figure 2. Anomalous dispersion curves showing the extinction coefficient k (related to absorption) and the refractive index (n, showing the local fluctuation in speed of light).

orbital frequency and the photon frequency is seen in the local high refractive index (n) at resonance. This high n, as in a lens, focuses the large-diameter photon (e.g., micron size) into the smaller atomic region (Angstrom size). The change in frequencies during the energy exchange is important also. The rates of change in orbital and field frequencies (inversely related to the wavelengths shown in the figure) alter the effective frequency of the incident photon. Again, interactions of '3-body' coupled resonances must be explored in detail (but not here).

We will make another assumption at this point that affects the later sections of this paper.

Assumption: Just as the electron and its bound EM-field are coupled and frequency-related during the variations (oscillations) of the electron orbit within an atom, these two oscillators are coupled and frequency-related to the energy and frequency of a third coupled oscillator, the photon, during the emission or absorption of that photon.

This assumption is an attempt to explain the observations and physical 'laws' that state the photon to be the coupling mechanism between atoms. If this assumption is correct, and the relative frequencies of the three resonators alters the absorption and emission probabilities, then the nature of the potential well that a charge 'inhabits' will also affect the probability of transitions and even their nature.

3.3. Coupler dependence on the shape of potential

All atomic spectra are generated by electrons in a Coulomb potential (although one that may be influenced by its environment). This is not necessarily the case for gamma rays and, as will be seen, not always the case for an electron in the deep Dirac levels. Figure 3 illustrates a model of a useful nuclear potential (Woods–Saxon) [13], showing the different regimes, and an experimentally determined potential showing application of the model to a real nucleus (that includes the Coulomb barrier). The model has a harmonic oscillator regime, where a change in energy does not alter the nucleon frequency. It also displays a square-well regime where the frequency of a nucleon increases as it is raised in the potential well (and is lowered as the nucleon drops deeper into the well). A regime not shown explicitly is the

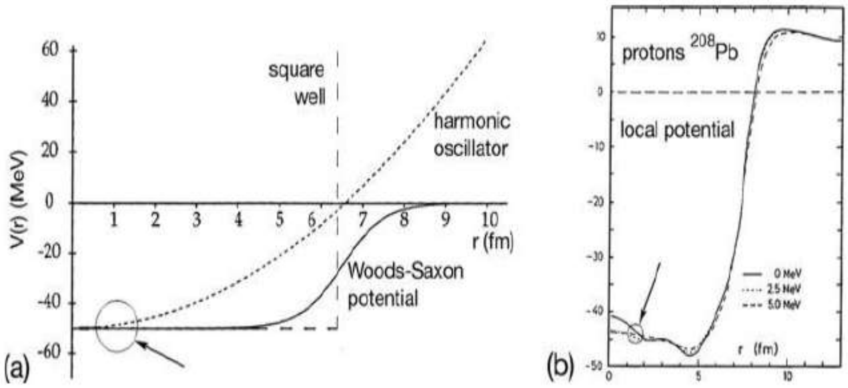

Figure 3. (a) A nuclear-potential model and two simplifying approximations. (b) A measured nuclear-potential profile.

region near the escape energy where the shape of the potential 'turns over' and is much closer to that of a Coulomb potential. In this region, the nucleon frequency decreases as it is raised in the well and increases as it drops into the well.

Since the nuclear forces are short-ranged (< 1 fm), the inner nucleons of a multi-nucleon nucleus contribute little to the shape at its edge. Thus, a low-Z nucleus would have little or no 'flat' region in its center (unlike the high-Z nuclei of Fig. 3). The nuclear radius ($R = r_{\rm o}A^{1/3}$, with $r_{\rm o} = 1.25$fm) is much smaller.

If the assumption in the last section is valid, then protons near escape velocity of the nuclear potential can more readily produce photons than those much deeper in the well. They are moving faster and have a stronger acceleration (thus greater EM field), because of the square-well potential further in. This ready emission of energy would be a means of 'containing' protons within the nuclear potential. If in a region of the potential where photons are not readily formed, then a nucleon tunnelling out of the nuclear potential well (through the Coulomb barrier) may be the dominant mode of changing nuclear energy levels. Other nuclear decay modes also can become dominant. The potential-dependent coupling described above now leads to the question of the electron's deep-Dirac levels (DDLs) that are at the bottom of their Coulomb potential [14]. What are the real shapes of the local potentials and the consequences of that shape?

4. Radiation to and from Deep Dirac Levels (DDLs)

Normal atomic electron orbitals are narrow minima (resonances) within a Coulomb potential. The bound electrons are moving around in an Angstrom-size well with perhaps a low Fermi-size hard-core center. Deeper levels have much smaller radii. To go to a lower orbit (from an excited state) and maintain the 'closed' orbit of an integer number of the deBroglie wavelengths, the electron must increase both its kinetic energy and momentum. The change in energy required is larger at the lower orbitals. At high levels, near ionization, the orbits widen out rapidly and the energy levels come closer together.

Figure 4 gives the electron kinetic energy (KE in meV) as a function of distance from a proton [5]. The dips (minima) in the curve represent various resonances, known and possible. The depth of the dips is not real, only representative. Does a resonance actually change the KE? It changes the probabilities, but does that represent a potential? The single Compton wavelength should generate a resonance with a corresponding local minimum in the electron's energy level. Has this level ever been seen? The deep-Dirac levels for hydrogen have been predicted at a binding energy, BE $= \sim 500$ keV. Is there a resonance there? There appears to be a change in the shape of the potential, because now the centrifugal barrier is a large portion of the available potential well. To get this much energy from the Coulomb potential alone, the

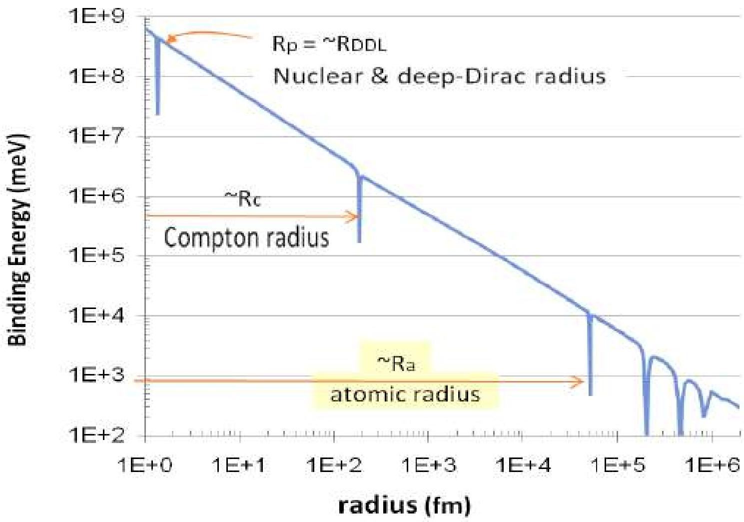

Figure 4. Ranges for kinetic energy vs. radii of nuclear, DDL, and atomic-electron orbitals.

electron must be within a Fermi of the center of the proton. The spin coupling between the electron and proton may allow the orbit to be larger. However, there are presently too many unknowns in this region to properly predict levels.

Nevertheless, much can be suggested about the DDL orbits. They are at or near a true minimum (the maximum kinetic energy in Fig 4). The energy predicted by the Dirac equations [7] can only be order of magnitude, since the $1/r$ Coulomb potential is not assumed to be valid to below 1 fm and no nuclear magnetic moment has been included in the Hamiltonian. The centrifugal barrier confines the electron to near-circular orbits and prevents formation of 'normal' s-orbitals that would pass closer to the proton center. Classically, relativistic orbits with too little angular momentum would simply 'spiral-in' to the proton center (whatever the nature of that center). The only paper to calculate details of the DDLs, gives the DDL ground state to be an $n = 2$ orbit, nevertheless Maly and Va'vra [3] still classify it as an s-orbit (its angular momentum is less than h so that $\ell = 0$).

Maly and Va'vra also find additional, deeper, orbits with higher angular momentum (high ℓ implies more circular orbit) and kinetic energy. This is reasonable since the lowest ℓ values produce rosette orbits (orbital paths oscillating between a non-zero inner and an outer limit). More circular orbits can have a smaller average distance from the proton center and therefore their average distance from the proton(s) may be deeper in the Coulomb potential. The asymptotic limit is 511 keV. This added energy goes into relativistic mass that increases the angular momentum of the circular orbit. At some point, the mass increases faster than does the relativistic velocity. The reduction in average orbital radius with addition of energy increases the electron frequency, but no resonances have been considered on this inner branch away from the DDL ground state. (Magnetic Landau levels and the neutron may be options on this branch.)

It is this ability to increase frequency with added energy that makes the DDL such an important 'tool' in the cold fusion story. This trait, impossible in a Coulomb potential, is also that of the photon. Thus, the DDL electron can act as a coupling medium between the nuclear protons, which might be in the Coulomb-like regime of the nuclear potential well of a femto-atom [15,16], and the lattice electrons.

4.1. Nuclear to DDL energy transfer

A nucleon, in a square-well portion of a potential, will decrease its frequency as it decays from a more energetic state. As, or if, it moves to the bottom of a nuclear well, a particle becomes a simple harmonic oscillator (SHO) that will not change its frequency as it changes its energy. No nuclear potential well will be as conducive to forming photons as the atomic potential, since the high mass and small dipole moments of nucleons more than compensate for the strong acceleration field of the nuclear potential. However, the nuclear square well and SHO further impede photon formation because the inverted changing of resonance frequency of a nuclear proton and that of a nascent photon would appear to play a major role. This difference in change of resonant frequency with particle kinetic energy is critical to the following discussion.

From the nuclear-potential model (Fig. 3), as an excited nuclear proton decays from the quasi-Coulomb potential region, it moves into the square-well type region ($r = < 1$ fm?) and its ability to form photons will diminish. In these deeper parts of a nuclear potential, where the nucleon frequencies decrease as their kinetic energy decreases, photon formation and emission is less likely.[a] Therefore, internal conversion or other mechanisms become the dominant decay modes [2].

If DDL electrons are present about a nucleus, the situation is different. Proximity makes the excited-proton EM field very strong for the full DDL electron orbit (not just a small portion of it) and excited-nucleon and DDL-electron frequencies are comparable. Direct proton EM coupling to an electron in the DDL Coulomb branch is thus a rapid decay path for excited nuclei in the middle regions of the nuclear potential well.

The point to remember is that, because DDL electrons have two branches through which they can absorb energy, they are able to readily and directly draw energy from excited nuclear protons *regardless* of which nuclear-potential regime they inhabit. The inner branch leads to formation of neutrons, if sufficient energy is available in this mode. Whether this neutron formation bypasses, or simply accelerates, the weak interaction is still to be determined.

4.2. DDL electrons to atomic electrons

The next step is similar. The DDL electron(s), now with excess energy from a decaying proton, is able in turn to transfer energy to the bound electrons of the host lattice atoms. Nevertheless, the method of energy transfer to the lattice electrons is not through the expected modes.

Proximity coupling, via photons from relativistic electrons, could predict extremely high transfer rates. However, the very small dipole moments and extremely high frequencies of the DDL orbits prevent this. Furthermore, if a DDL electron has absorbed energy directly from a proton in a nuclear-Coulomb mode, then the DDL electron would be excited into the near-nuclear (inner) mode. It would have increased its frequency to try to match that increase of the decaying proton. If in turn, the excited DDL electron tries to lose that excess energy, its decay mode from the inner branch is *not* compatible with photon production.

Figure 5 gives some perspective on the relationship between the nucleon, DDL electron, and atomic-electron frequencies. The DDL- and nuclear-orbital frequencies are only rough approximations, since the values depend on the model selected. Nevertheless, because of the near square-well nuclear potential, excited nucleons have frequencies even

[a] Some physicists will insist that an electron or nucleon changing state will annihilate at state A and be recreated at state B. I, agreeing with Feynman, will insist that the particles move continuously along a path from one state to another. If this is so, then the EM-field, always present with charged particles in motion, will reflect the variations in potential along that path. These variations in the EM-field are critical to the formation and departure of a photon [9]. Extending this logic, the shape of the potential well will alter the nature and probability of a transition. It will alter the preferred mechanism for a particular transition. It is in this spirit that I discuss the energy transfer between excited nucleons and the DDL electrons. Under these conditions, fixed energy levels need not be considered. The transfer of energies by a non-photonic EM-radiation mechanism is possible and much more probable than by any other mechanism.

closer to those of the DDL electrons than those of nucleons in the ground state. Thus, energy transfer is increasingly more efficient for the excited nucleons. It can be seen that because of the difference in frequency, the coupling between nuclear protons and atomic electrons would be negligible. The situation is worse for DDL and atomic electrons. This is why the DDL population is so low. The DDLs and atomic levels cannot readily communicate. However, electrons in those levels can transfer energy in other ways.

How does a DDL electron, with excess energy from a decaying proton, transfer energy to the bound electrons of the host lattice atoms. The inner branch is compatible with direct stimulation of the atomic electrons. In this regard, the DDL electron is like the photon and would be a case of a fermion, rather than a boson, being the mediator between two fermions.

The extreme difference in frequency between the DDL and atomic-orbit electrons does not present an insurmountable problem since an s-orbital lattice electron quickly passes close to its nucleus at relativistic velocities. The strong DDL electric fields from the same or adjacent deep-orbit atoms will perturb lattice-electron paths during this period of velocity matching in a non-linear region (near its nucleus) and allow significant direct energy transfer. This process is like that of a baseball bat rather than like resonant photon transfer. Stable resonant states are not required for such energy transfer.

4.3. The DDL baseball bat

As an example of a DDL electron's influence on a nearby s-orbit atomic electron, assume that the DDL electron's **E**-field (at $> 10^{23}$ Hz, Fig. 5) is strong enough to accelerate an electron to an average velocity of 10^8 m/s for a fifth of a DDL electron cycle (2×10^{-24} s). The atomic electron will deviate from its path by 2×10^{-16} m or 0.2 fermi. Normally, during a whole DDL-electron cycle, the atomic electron will fluctuate by this amount and never be affected. If, however, it is shifted this much during perigee, when it might be as close as 10 fermi from its nucleus, this much shift in its orbit may change the atomic electron's orbit by 2 keV. (See Fig. 4, where the electron energy at 10 fm is $\sim$ 80 keV and at 8 fm $E = \sim$ 100 keV. Divide this difference of 20 keV by 10, to approximate a 0.2 fm shift, to get a $\sim$ 2 keV shift in energy.)

A 2 keV shift would not be the most common energy transfer. But it is not a maximum either. Each neighboring lattice atom has multiple s-orbit electrons and they transit their nuclear region in the $> 10^{16}$ times per second range. Many more next-neighboring lattice atoms are not as strongly affected, but might absorb 100s of eV per s-orbit pass.

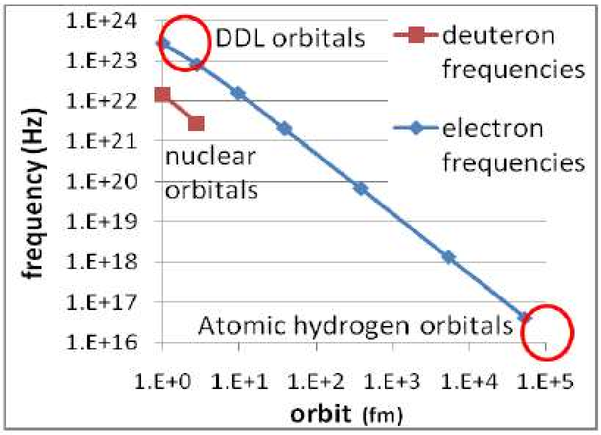

Figure 5. Ranges for frequencies and radii of nuclear, DDL, and atomic-electron orbitals.

Most of the time the phases between the DDL and atomic electrons would not be 'right' for such large energy transfers. Furthermore, the energy added to, and subtracted from, the s-orbit electrons is only accumulated on a statistical basis. Nevertheless, energy can be transferred from the nucleus to the DDL electron and on to the lattice at a very high rate. The transfer is at a rate that would cause ionization and yet not cause damage to the lattice.

4.4. Observables

The interaction between the excited nuclei and the DDL electrons would not be directly observable except in a few cases. The case when a pair of femto-hydrogen atoms (hydrogen with DDL, instead of normal, electrons) [8] join and produces a deuterium atom would probably also produce a neutrino. Neither a single deuteron nor the neutrino could be easily identified nor as being correlated or even attributable to the same event.

The keV excitations of bound lattice atomic s-orbit electrons would lead to X-rays that have been observed in cold fusion experiments. There would be two types of X-rays. There would be those, with a broad range of energies, from Bremsstrahlung produced by energetic electrons ejected by the initial 'kick' from the DDL electron that far exceeded the ionization energy. There would also be nearly monoenergetic X-rays from electrons falling into the emptied s-orbits. Nevertheless, the severe local disturbance (ionization and strong EM fields) might still spread such normally spectral energies beyond identification. Since there are higher-n s-orbital electrons, a whole range of lower-energy EM radiation would also be available. But, they might be even harder to observe, if the events were not taking place on the surface and an appropriate 'window' or internal spectrophotometer were not available.

5. Summary

From this author's last year's and this year's ICCF papers, we can draw a fairly complete picture of interactions and events assuming the predicted properties of a DDL electron and the known properties of nuclear protons. This paper dwells on the energy transfer between excited nucleons and the DDL electrons and then to the bound electrons of the lattice atoms. Many of the properties of this exchange process are described below. Note that both the nucleons and the DDL electrons have two frequency-dependent modes.

5.1. Protons to DDL electrons

- **Processes to increase energy transfer (no large effects)**
  - (a) Excited nuclear protons (in the square-well potential regime) have higher frequencies (closer to DDL electron's resonance frequencies) than do ground-state protons.
  - (b) Decaying protons (in the attractive Coulomb-like nuclear-potential regime) may significantly decrease their orbital radius during this process and thereby increase orbital frequency, acceleration, and radiation field. This increases their net coupling to DDL electrons being excited into the inner branch, which also increase their frequency as they gain energy.
  - (c) Exciting DDL electrons into their Coulomb branch will lower their frequencies and bring them closer to the nuclear-proton's resonant frequencies.
  - (d) Energy added to DDL electrons, in the Coulomb regime, increases R_{DDL}, and thus their dipole moments. This increases coupling to nucleons.
- **Processes to decrease energy transfer**
  - (a) Protons that are lower in the square-well regime have lower frequency. This reduces their radiation field intensity and moves them further from DDL frequencies.

(b) Decaying protons, in the square-well regime, lower their frequency as they lose energy. This lowering reduces their radiation field intensity and their coupling to forming photons and to DDL electrons in the inner branch, which increase their frequency with added energy.

5.2. DDL electrons to lattice electrons

- **Processes to increase energy transfer**
  (a) Collisions of DDL electrons with lattice valence electrons approaching a nucleus transfer energy directly.
  (b) Collisions give DDL electrons angular momentum that allows them to radiate photons (not possible before).
  (c) Exciting DDL electrons into the Coulomb branch lowers their frequency (closer to that of bound lattice-electron's orbital resonances).
  (d) As DDL electron excess energy (from excited nucleons) approaches its binding energy, its frequency overlaps with lattice atomic-electron states.
  (e) At close to DDL-electron ejection, both frequency and spatial overlap occurs with the more numerous d-orbital lattice electrons.
  (f) DDL-electrons, with higher binding energy, have greater EM radiation fields and thus are in a better transfer regime with respect to free lattice electrons.
  (g) Energy added to DDL electrons, in the Coulomb branch, increases R_{DDL}, and thus their dipole moments.
- **Processes to decrease energy transfer**
  (a) Increasing R_{DDL} lowers DDL electrons' acceleration and thus their EM field (large effect)
  (b) Excited DDL electrons in the Coulomb branch have lower velocities and thereby a reduced relativistic term (3–4× effect)

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