Fusion by Pseudo-Particles, Part 2
The Challenge of the Present

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Fundamental Physical Concepts: Their Technical and Social Consequences

The need for renewable, inexpensive, pollution-free energy is apparent, and the solution is overdue. Devices based on multiple LENR processes are in the making. The advantages have already been detailed by Prof. David Nagel (*Infinite Energy* #103, "Potential Advantages and Impacts of LENR Generators of Thermal and Electrical Power and Energy"). Therefore an outline of possible physical concepts and techniques for building them is useful for the researchers in this field.

The mainstream school of thought in physics is a reductionist one. This Greek analytical method goes against the oriental, "holistic" view. So far it has been rather successful, shown by the history of science and technology. The simplest interaction is between two bodies, via force fields, or in a more extended form as chain reactions. But this kind of simplification is counterproductive for us, as shown below, and this is an understatement. In fact, it is devastating—especially in the field of fusion research.

To put it bluntly, the author will argue that muon-catalyzed fusion—as an example of three-body interactions—should be the fundamental physical and technical model, the driving force behind controlled fusion research. Further, the technical concepts of charge shielding and resonant processes should be emphasized as well. Together they make possible technically viable inventions, which are driven by the fusion process based on protons, instead of deuterons and tritons, as we have only protons in "unlimited" quantity, not deuterons and especially not tritons. The physical principles and their practical implementation is summed up in Table 1. The relevant technical processes and inventions were discussed in Part 1.

The well known D + T → He + n + γ (hot fusion) two-body reaction is technically sound, and proven beyond doubt. It is the fundamental process of the dreaded H-bomb. Its development in the U.S. carried a price tag of about $6 trillion—along with its means of delivery, like submarines, airplanes and rockets. The apparent destructive power impressed the corridors of power elsewhere, so the Russians, the Chinese and perhaps the British footed a similar bill.

The success of this two-body reaction gave pride and previously unknown access to nearly unlimited funding to physicists. The H-bomb mechanism has a trap, though, which is well known. The reactant D and T nuclei must have a very high temperature in order to overcome the Coulomb barrier. Edward Teller, S. Ulam and Andrei Sakharov came up with the right technical solution—to explode a small fission (plutonium) bomb to reach ignition. The need for this extremely high initial temperature still pervades the mind of mainstream fusion researchers, for both the inertial and the magnetic confinement line of R&D.

Bomb or Reactor — Not Both!

However, there is an essential, albeit neglected difference. In a good bomb all the fuel should be burned up as fast as possible, as in all explosive devices. Devices generating controlled energy obviously require a slow, gradual fuel consumption. Thus the fusion process should be slow, and non-explosive, so the door is wide open for a fundamentally different process and practical devices.

It is a grave mistake to forget this difference. There is an extreme price to be paid for ignoring it. Nearly all hot fusion (thermonuclear) designers are unaware of this distinction—they "like it hot."

Coulomb repulsion between light nuclei can be substantially reduced by a negative charge (if it is close to the reactants), thus reducing the repulsion, but it demands a three-body interaction at least.

In mainstream hot fusion devices, electrons do not shield the charge of any reactants; thus Coulomb repulsion is in its full force. The high temperature is a non-negotiable demand to overcome the repulsion forces between the two reactant nuclei, D and T.

The concept (not the hardware) of D – T fusion of the H-bomb became a real weapon of mass destruction, potentially wiping out not only towns or countries, while preventing a world economy of sustainable, pollution-free energy. New generations of hot fusion devices based on the D + T two-body reaction have always proven to be the "emperor's new fusion device." The "insiders" see them working, but the "outsiders" claim that they do not work. This author falls into this latter category. Money spent on hot fusion research is a waste of public money.

To put it in a different way, high-energy two-body interactions are suitable only for explosive fusion. They are fundamentally flawed for slow, controlled fusion with any meaningful economic use. On the contrary, charge-shielded (minimum) three-body fusion interactions are useless for explosions but suitable for LENR reactions. Constructing them requires engineering skill and insight, but this is the only feasible way to controlled nuclear reactions.

It is a pity that none of the textbooks written about controlled thermonuclear fusion describe the importance of charge shielding, which makes it possible for two protons to approach each other close enough that the attraction by strong interactions overcomes the reduced electrostatic repulsion. Instead, they come up with technically cumbersome "confinement" proposals, and with a non-renewable tritium reactant, both of which create more problems than it solves.

The sharp difference between the mindset of "power physics" versus "smart engineering" described in Part 1 is quite apparent here.

A Practical Model for LENR Developers

There is a way out, well-known to the mainstream. This is "muon-catalyzed fusion," known to those "skilled in the art," though its practical utility is in doubt. First, here is a glimpse at some relevant and sincere mainstream opinions:

Francis F. Chen, a veteran of thermonuclear fusion research, describes a series of unsuccessful attempts in his recent book, *An Indispensable Truth: How (Hot) Fusion Can Save the Planet* (Springer, 2011). The history is summed up under the title of "half a century of progress," where 200 Tokamak nuclear reactors were built, but none of them have ever reached the break-even threshold.

In Chapter 10, "Fusion Concepts of the Future," only two-body, "hot" reactions are considered, such as $p + B^{11} \rightarrow 3\alpha$; $He^3 + Li^6 \rightarrow 2\alpha + p$; $p + Li^6 \rightarrow He + \alpha$, etc., which are all above the 50 - 100 KeV ignition range.

Inertial confinement is treated from a distance in some pages, with a mild skepticism. "Cold fusion" and "muon fusion" are described under the subtitle "Hoaxes and Dead Ends." Are they?

In another book, *Plasma Physics and Nuclear Fusion Research*, Richard Gill (Academic Press, 1981, p. 31) openly states the mainstream view: "Plasma physics is not a pure academic exercise, although there are challenging fundamental problems to be solved. Neither is it a purely applied field which will earn money for the lucky holder of the right patent." The meaning is clear: Don't ever dare to think differently than the in-crowd does, or else. . .

In 2008, a $96 million device, the "national compact stellator," was thrown out during its construction at Princeton's Plasma Physics Lab without a blink of the eye (*Physics Today*, July 2008, p. 25).

Fusion research (and energy in general) is as much a social problem as a physical and engineering one. The indoctrination begins at school (see, "A Simple Facility for Teaching of Plasma Dynamics and Plasma Nuclear Fusion," *American Journal of Physics*, Vol. 56, #1, 1988, p. 62). When fusion is mentioned, the thermonuclear option is described, as if nothing else could exist. I referred to this mindset when I wrote about the "emperor's new fusion device."

Muons (negative heavy electrons) are capable of forming exotic atoms or exotic molecules between deuteron nuclei, or a muon may bind a molecule of tritium and deuteron, where fusion takes place. In heavy electrons, a molecule is formed where the equilibrium orbit (*i.e.*, the radius of oscillation) is much shorter than with the "ordinary" electron, so strong nuclear forces come into action (see Table 1-1 and 1-2).

Negative Muon-Catalyzed Fusion

It is an experimentally established fact that muons catalyze D – T fusion in a chain of as many as 150 - 200 reactions. The muon has an average life of about $2.2 \cdot 10^{-6}$ sec. Their creation requires about 5.3 GeV of energy (though its mass at

Table 1. Physical principles and their practical implementation.

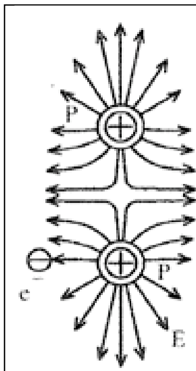

Table 1-1

Ordinary hydrogen plasma. Large electron-proton distance, weak shielding, strong Coulomb repulsion. Electron-proton binding energy ~1.5 eV, low. Fusion possible only at very high energies. (Neutrons are not shown.)

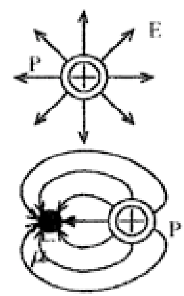

Table 1-2

Efficient charge shielding by heavy-electrons, called muons. Muon-proton distance is only some Angstroms, binding energy is ~200 keV. Approaching proton or deuterium is only slightly repulsed, cold temperature fusion is possible. (Neutrons are not shown.)

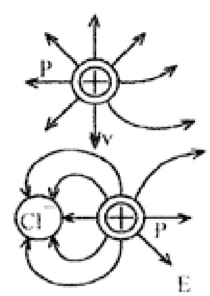

Table 1-3

Charge shielding by a heavy negative ion: J. Papp's solution. The shielding is partial, therefore the incoming proton must have a high velocity. Extreme local non-equilibrium.

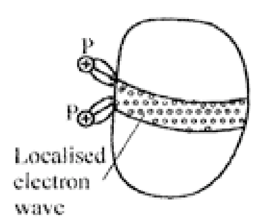

Table 1-4

The Coulomb repulsion of like protons, above the electron wave on the surface of a small surface. The density of electron wave must be very high to attain enough electric field intensity. (Neutrons are not shown.) Polyneutrons may form by this process also.

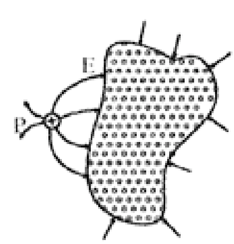

Table 1-5

For a charged dust particle, $p^+ + e^- + 0.7$ MeV = neutron+neutrino process is the most probable. Oscillating, resonant proton cloud, colliding with dust particle, is a reliable source of neutrons. Neutrons may interact with protons and surface nuclei.

rest is only 106 MeV). The process is not economic because even a 200 D - T fusion reaction yields only about 3.5 GeV of fusion energy (W.N. Cottingham, D.A. Greenwood, *Introduction to Nuclear Physics*, Cambridge Univ. Press, 2001). Thinking along this line is considered a dead end. This is the ultimate cold fusion since this reaction takes place preferentially in a liquid mixture of D - T. The reaction takes place in pure liquid deuterium, or in D - H mixtures, but not in pure liquid hydrogen.

The idea of heavy-electron (muon) catalyzed fusion was conceived by U.S. researchers, notably Louis Alvarez, but independently by bright Russian theorists like Igor Tamm, Yakov Zeldovich and Andrei Sakharov. But they never meant to create a device for that. Australia's Star Scientific Company, led by Hungarian-born Stephen Horvath, still sticks to the muon charge shielding as a technical solution. (An earlier U.S. patent was granted: 4,454,850/1984.)

However, the essence of this muon-catalyzed fusion process has important lessons for us. How are heavy (m_μ/m_e = 207) muons able to catalyze a fusion in a liquid D - T mixture, at extremely cold temperatures? Due to its high mass, the muon gets so close to a nuclei, so that their charges screen and neutralize each other. The D - μ or T - μ doublet is electrically neutral even from a short distance of 100 - 200 femtometers, within the range of strong nuclear forces. Any such electrically neutral doublet can be approached by positive nuclei without significant Coulomb repulsion. (There is a similar idea behind the BlackLight Power Company of Mills.)

It is possible only due to the high mass of the (negative) muon. Why? Because both binding energies and distances depend on the scale of m_e/m_μ. Thus the characteristic distance between the D and T nuclei, or D - D nuclei, is reduced by a factor of ≈ 200. When an electron binds H isotopes into a molecule, their characteristic distance is about 1 Å (10^{-8} cm). This is reduced by a factor of 200 to about 500 fm, which is short enough for the strong interaction to start fusion, via tunnelling, in about 10^{12} sec. The characteristic energy scale of atomic, molecular physics with electrons is the Rydberg unit which is $m_e(e^2/4\pi\varepsilon_0)^2/2\pi\hbar^2 = 13.6$ eV while with muons it is 2.81 KeV. The liquid of this exotic heavy-hydrogen/heavy-electron has an extreme density, which cannot be attained by any confinement, or by any extreme engineering.

How does the heavy muon approach the nuclei, but does not fall into a nucleon despite the Coulomb attraction? Ostensibly it is due to the repulsing effect of strong vacuum fluctuations near the nuclei (due to the extreme density of the electric field). The light electron is repelled by vacuum fluctuations to a distance of about 1 Å, but the heavier muon gets much closer, due to its 207 fold inertia. Therefore it has a much better charge screening, and thus catalyzes a fusion reaction. These exotic atoms are extremely dense. Laser driven, X-ray driven or heavy ion driven D - T fuel pellets cannot be compressed with inertial confinement methods anywhere close to these extremes.

The mainstream view is that making (negative) muons requires too much energy so this kind of charge screening process is only of theoretical interest. Charged, emergent heavy pseudo-particles (the subject of this paper) are not the "weapons of choice" for thermonuclear engineering.

The same problem arises when neutrons are to be formed by forcing an electron into a proton. Vacuum fluctuations repel the light electron. But if it is a part of an electron cloud and bound tightly to it, it cannot be repelled easily: neutrons are formed, though ostensibly by electroweak interactions (Widom & Larsen).

However, amateur inventors (listed in Part 1) have accidentally stumbled onto several solutions. Instead of creating real heavy electrons, they created a wide variety of heavy virtual or pseudo-particles, which perform the same function (charge shielding) as heavy muons. All of these pseudo-particles have a negative charge, but usually not just a single electron but a multitude of them, and much heavier ones than a single electron or even a muon. The misconception in the mainstream view is that the quasi-particle must be in a closed orbit around the prospecting nuclei to be fused for a while in order to commence the fusion reaction.

Those inventors stumbled onto processes where an elusive pseudo-particle, usually a cloud or wave of tightly compressed electrons, does the same job, but without closed orbits. Such a dense pack may consist of millions of tightly compressed electrons and protons oscillating, and advancing in a coherent wave, usually on a conducting metal surface, or imprisoned in a solid, nanometer-sized dust particle. The former is termed broadly a "plasmon polariton"; the latter is a "dusty" or "complex" plasma. Both systems can be driven into resonance when the electron charge density is at its possible peak and when its field density and virtual or effective mass is heavy enough to have the same overall effect as that of a muon. These pseudo or "high effective mass" particles have been known to mainstream science for more than a decade. But neither phonons (volumetric electron waves) nor polaritons or nano-sized dust particles were considered of any use in nuclear phenomena because their charge shielding capability is of no use in their usual area of application.

Moreover, since the nuclear phenomenon which they induce is not accompanied by radioactive phenomena, the inventors did not think along this nuclear reaction line, (except for J. Papp). Lucky inventors did not understand the essence of micron or nano scale phenomena either on fine needle tips or inside small cracks on the surface of fine grain and dust. These are the usual sites of high-density, high effective mass electron waves.

Most probably Mizuno was the only researcher who stumbled onto proton induced electron waves in "proton conducting" ceramics as a special case.

Various pseudo-particle related charge-shielding phenomena are listed in Table 1. Most of them are based on pseudo-particles that are heavier than muons, whose most important feature is charge screening. However, these nuclear phenomena are never D + T processes, because tritium and deuterium were not available to inventors. In fact, all of their devices were based on ordinary hydrogen (or on even higher mass elements) as a "fuel," which is even more difficult for the mainstream view to accept. But there are other possible routes to achieve fusion than the high-energy D - T process, via an indirect process based on neutron generation and subsequent neutron capture processes, and/or H + D → He^3 type fusion with intense charge shielding.

What is a Plasmon Polariton?

There is quite a "fog" that consists of a "high effective mass" or "heavy" electron, and a further question is how to generate them usefully. The usual notion of a plasmon polariton or a resonant surface plasmon polariton is quite close to what we need to create. Let's try to clean up this fog, though in the appendix of Part 1 there was a partial introduction to the subject.

When an electromagnetic wave (usually infrared) hits a plain metal surface immersed in dilute (not fully ionized) hydrogen plasma, electron waves spread on the metal surface, and longitudinal charge density waves spread above it in the plasma. They are coupled by a high intensity electric field, but only inside the Debye shielding distance. The wave intensity is low for a large area metal plate, but good enough for, *e.g.*, a sensor in a pregnancy test. But when the surface area is small and permanent, like a thin wire, so that it cannot spread as a concentric plane wave (see Figures 1-6), the wave energy density may be high. This is interesting for us when we must approach the order of a MeV. (See this application as the blob of very thin silver wires of J. Jekkel in Part 1.) These waves are highly dispersive, and dissipative mainly due to the recombination between the ion cloud and the electron waves.

Tapered needle tips are even better than wires (see Figure 6) if we can get them (Correa, Chernetsky, Shoulders, Meyer). Even external, sharp-edged current pulses can excite them, not only thermal radiations. Zero dimensional objects (small, nanosized cavities) termed as quantum nanodots (Figure 4) or nano dust particles (Figure 5), are even better objects, since the energy of excitation cannot escape. With proper matching of cavity size, dust particle size and excitation frequency, giant amplitude electron wave oscillations are generated.

In Part 1 some of the "trade secrets" of several obscure, forgotten inventions were discussed, and their varied methods of plasmon wave generation were shown, along with their strengths and shortcomings. Resonances are vital in most of these wave generation processes, but these are standard engineering methods. The same applies to the generation of charged dusty plasma. The coherent wave feature in this case is the movement of trapped electrons on the surface of small dust particles.

Electron waves can be created in surface cavities (see Figure 4), cracks and protrusions of deuterated metals or in metal hydrides in "classical" electrolysis-based devices. In fact, the first two letters for low energy nuclear reaction come from the fact that in proton + electron or proton + deuteron reactions these high intensity charge waves are just catalyzers created by a small amount of resonant energy because they shield the Coulomb repulsion down to a technically acceptable low level.

Efficient coupling of the hydrogen plasma and electron waves can mediate gradual energy accumulation up to the required MeV order wave energy, which in turn can be used for inexpensive "local manufacturing" of slow neutrons. These low speed "cold" neutrons usually do not escape from

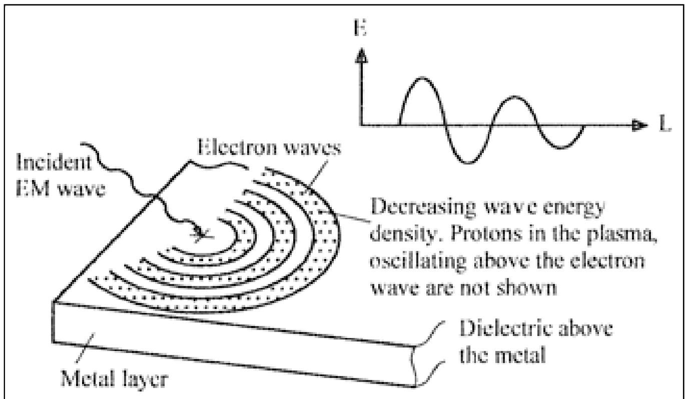

Figure 1. Plasmon polariton quasiparticles oscillating on and above a conducting infinite plane.

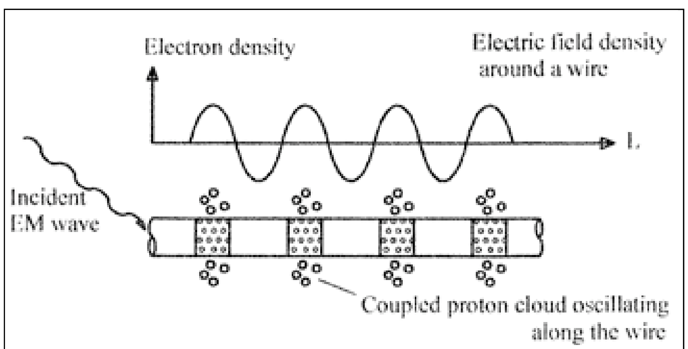

Figure 2. Infinite length, steady wave amplitude along a wire.

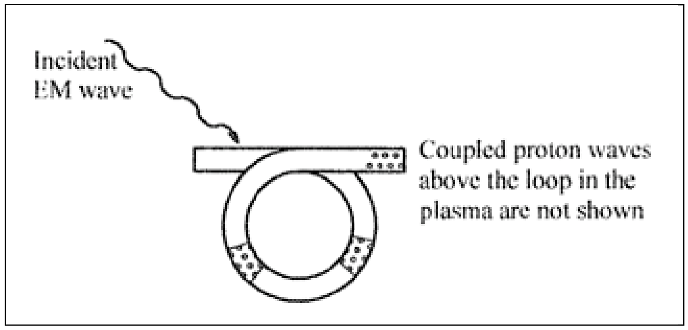

Figure 3. A piece of closed loop wire. Amplitudes could be increased by resonance, due to finite size.

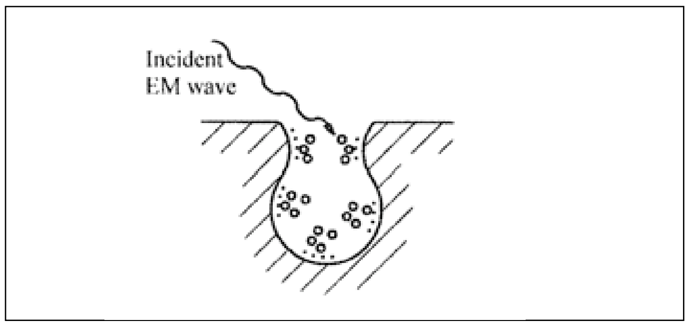

Figure 4. Resonant standing charge density waves within a cavity. Above them oscillate hydrogen (proton, deuterium, tritium) isotopes of a plasma.

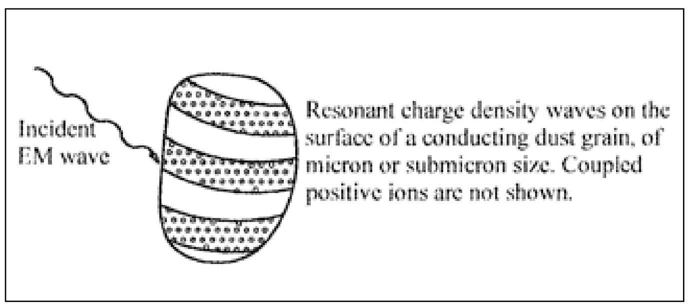

Figure 5. Case of an isolated conducting grain. Oscillating positive charges are not shown.

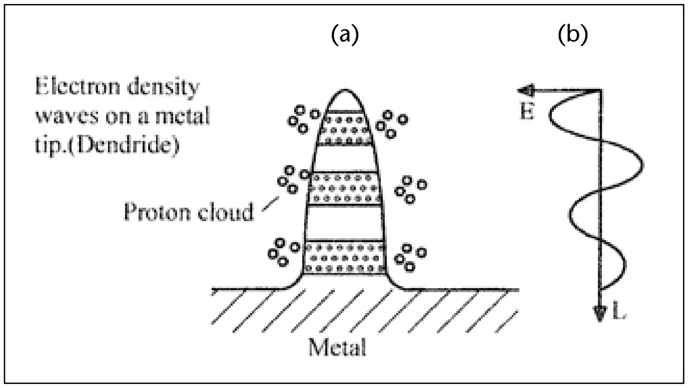

Figure 6. Electron waves along a tapered metal tip. Note the amplification effect along the tip.

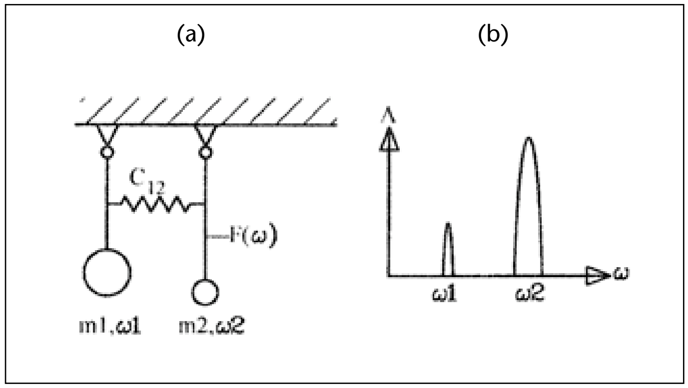

Figure 7. Coupled oscillators. The coupling spring constant C_{12} between the two pendulums is constant.

the device, because they have a very large reaction cross section, and thus react with the nearest nuclei. Consequently we don't need a high temperature or any confinement, like those in mainstream D - T thermonuclear monster devices. In our model, plasmon polaritons are tightly bound, coupled electron waves and proton (deuteron) waves in diluted, not fully ionized plasma. Their high inertia-high mass is the consequence of the high mass of the proton cloud, which oscillates, but at a smaller amplitude than the coupled electron wave. Now we have to describe the specifics.

Let us start with Papp's process, which stands out from the rest since it uses a negative ion, Cl^- for charge shielding, and a chain of inert gas atoms in impedance matched collisions to accelerate protons. Ostensibly, there are three possible separate events.

Some LENR Processes Using Quasi-particles

1) A fast proton accelerated by a "lucky chain" of collisions of rare gases hits an electron on the shell of the Cl^- ion, consequently creating a neutron: p + e- + 0.75 MeV → n + neutrino. Of course, the energy of a high speed Xe ion must be transferred with good efficiency to reach that goal. This step requires input energy, which is provided by a high-voltage spark between two conical electrodes. The 1 - 2 kV input voltage wouldn't be enough, but in a gas discharge at the "high-energy tail" of the Maxwell distribution, it is available for a few atoms. There are also acoustic focusing tricks in the invention to further boost this amplification effect.

2) When there is an inexpensive, continuous supply of low-speed, high cross-section neutrons, n + H → D + E, n + D → T + E, reactions may take place, none of them requiring input energy, but each of them producing energy E (as a combination of kinetic energy and electromagnetic radiation).

3) Due to the charge shielding capability of the Cl^- and the high speed protons, the $H_1^1 + D_1^2 \rightarrow He_2^3 + E$ or $H_1^1 + T_3^1 \rightarrow He_4^2 + E$, reaction takes place. In this type of reaction, all features of the Papp process are necessary, that is, local charge shielding by Cl^- ion and local acceleration of protons.

The Cl^- ion is not a pseudo-particle. It is a heavy, negative ion but it does serve the same purpose as a pseudo-particle, or a muon, though it is not as effective for charge screening, and therefore it requires extra proton speed.

The rest of the processes, most inventions, use dense electron waves either formed on a surface or in a volume, listed in Table 1. Neutron generation with a pack of electrons is the first step of these inventions. Resonant, high-amplitude electron waves can be generated on a fine wire mesh (Jekkel, Gray), in small cracks or cavities (Moray, Puharich, Meyer), or on Ni surfaces, absorbed by light or heavy hydrogen (Patterson, Preparata, Piantelli, Celani, BARC, etc.).

When the energy of the electron wave is low, *e.g.* when it is excited by weak intensity infrared radiation, it may generate only low-amplitude surface plasmons, and then neutron generation does not start.

Lacking a minimum threshold level, the wave acts only as charge shielding. Then only heavy hydrogen reactions (D + D → He) may take place (Arata & Zhang). In order to utilize a light hydrogen isotope as a fuel, efficient charge shielding is necessary with high-amplitude, very intense electron waves.

Tips of fine needles (Shoulders, Chernetsky, Correa) have a double purpose. First of all, their potential difference may accelerate protons to some keV energy level and then it may hit the massive surface electron wave, where the acceleration by the continuously tapered tip is an amplifier, just like Papp's chain of collisions. This is the usual proton, electron → neutron reaction. However, now a whole wave of synchronously moving, accelerating electrons collides with the proton. This wave-like, high mass emergent pseudo-particle is of real technical use, relatively easy to produce, *e.g.* compared to "neutral beam heating." Using the charge shielding capability of extreme electric fields on the needle tip, H + D reactions may occur, along with D + D type reactions. The D might be generated *in situ* from n + p reactions, or added as fuel from outside. Wire mesh or needle tips can open access to light hydrogen as fuel, but it is not always economical. (There are usually few tips.)

Highly charged nanometer-sized dust particles serve the same purpose as needle tips, especially if loaded by electrons in an acoustically resonating plasma, but their number is higher, as they are present in the whole volume of the plasma (Tesla, Esko, Egely).

The combination of nano-meter length phenomena of electron density waves, charged dust particles and emergent features of pseudo-particles is a powerful, but hitherto neglected area of today's technology. The knowledge to drive them to the maximum level is extremely importance, and this is an understatement.

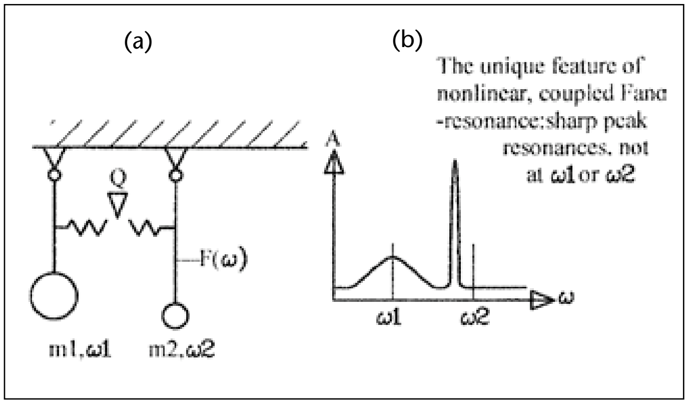

Figure 8. Coupled oscillators. The coupling strength is not constant, depends on the generated heat during LENR reactions. This is a simplified model.

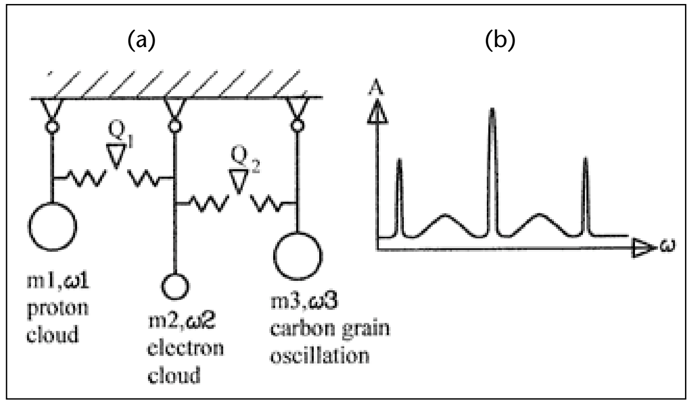

Figure 9. A more realistic picture of coupled, nonlinear Fano-resonances between the electron cloud, hydrogen isotope cloud and dust particle cloud.

The better the charge shielding is, the "colder" the different types of available fusion and neutron capturing processes are.

Mainstream thermonuclear fusion has an additional inherent problem. The reactants must have high energy to overcome Coulomb repulsion, but this adversely affects the reaction cross sections. It is difficult to make a good compromise because the ignition energy is in the range of minimum 15 keV for D - T mixtures, 80 keV for D - D reactions.

The inventions mentioned in Part 1 do not have this problem. Due to their multi-body, high-intensity charge screening, the energy level of the reactants is in the order of chemical energies of some eV or even below. Thus high neutron or hydrogen nuclear resonant cross sections are maintained with relatively simple technical devices. Thus charge screening provided by pseudo-particles connects the dots for various inventions of Part 1. The list is not complete; maybe readers are familiar with other similar forgotten inventions or discoveries.

The mainstream concepts for controlled fusion are thermonuclear ones, the same as the H bomb. Both inertial and magnetic confinement require steps of extreme engineering. That is a proper solution for a weapon, but not sensible, and not economic for a controlled, slow process.

The year Papp died (1989), Pons and Fleischmann came up with the right approach—charge shielding for the reactants. With a further daring step, they proposed a different reaction of D - D. But even their high scientific reputation was not enough to change the mainstream view, apparently due to vested financial and moral interests.

But the Pons-Fleischmann charge screening idea has not yet been refined on the engineering side. The distances between neighboring deuterium nuclei are not smaller in a palladium lattice than in liquid deuterium. But deuterium (or hydrogen) in the lattice or on the lattice surface opens viable technical possibilities for efficient charge screening. Obviously, the simplest solution is to be sought. Apparently, the earliest solution is the simplest, and that was discovered and disclosed by Nikola Tesla, in 1890, for the resonant "carbon button lamp." It was already possible then, but it is a must today.

There is a sad general rule: If there is an important discovery, it is always far from the mainstream thinking, and there must be at least five to six independent discoveries before it is accepted (*e.g.* radio, semiconductors, the aeroplane, antibiotics). Controlled, charge shielded fusion has been discovered at least 10 times, over about 120 years, and still counting.

The merits of different quasi-particle related methods are even better understood, if they are compared to some other, innovative, off mainstream hot fusion technologies. Only one of Bakhoum was mentioned in Part 1. We remind the reader that none of the two mainstream thermonuclear technologies (inertial and magnetic confinement) uses charge shielding or resonance. Consequently there is a need for initial extreme heating (termed ignition), then for further heating before break-even is reached, which is not yet economic. A further problem is T breeding with a lithium blanket. It is unavoidable, but an unsolved challenge. It might be solved later though at a continuously working reactor which does not exist. So even if turbulent plasma energy losses would be solved for Tokamak, or extreme sphericity demands met for D - T fuel, pellets (which drives their price tag up to about $1 million each) there is the tritium breeding problem. A base load 24 hours seven days a week is necessary for the system to work economically. (The rate is now about 1 shot/day.)

It is no wonder that some people started to think along alternative technical solutions, but most researchers still stick to the D - T reactions (which is the ultimate source of problems).

Some Improvements on the D - T Reactions By Charge Shielding

To illustrate the merits of charge shielding, some "off mainstream" solutions are listed below. They induce some weak form of charge shielding for the D - T thermonuclear process:

a) The concept of R.W. Bussard, of electrostatic confinement and charge shielding, is better known as "polywell" (U.S. Pat. 4,826,646/1989 and 5,160,695/1992). The main idea is to shoot an electron beam into an ionized deuterium plasma to reduce Coulomb repulsion. Partial magnetic confinement is still used (Ioffe bars), but the emphasis is on electron cloud and ion acoustic oscillations, to reduce the mean free path of deuterons. The electrons are smeared in the reactor core. This technical step alone has meant a substantially smaller, therefore less expensive reactor. The U.S. Navy footed the research bill and the work was carried out in secret. They were not afraid of Russian industrial espionage, but the wrath of hot fusion researchers.

The concept worked and they reached a break-even point but due to the Iraq war, their budget was slashed, and no private funding was available. Bussard died shortly afterwards.

b) There is another unorthodox hot fusion concept of heating the deuterium by resonance, and not by a plutonium bomb or neutral beam accelerators or giant lasers. The patents of Philo Farnsworth (3,386,883, and Robert L. Hirsch 3,664.920/1972) work along this line. These examples have been quoted to show that either some charge shielding or resonant heating improves the design.

However, the combination of charge shielding and resonance is necessary for meaningful success.

Table 2 lists concepts according to the degree of charge shielding and acceptance. The better the charge shielding is, the smaller the chance that the science community accepts it.

Nuclear Active Environments

Apart from Ni and Pd metal, there are a number of exotic alloys which are capable of propagating high effective mass electron waves due to their unique composition, like Ce, Cu_2Si_2, UBe_{13}, UPt_3, URu_2Si_2, $CeRh_2Si_2$, etc. See the complete list in Ben Breed's insightful U.S. patent application (0122940/2009).

Resonant nano dust carbon plasma is the favorite of this author, following the footsteps of Tesla. The charged, oscillating nanoparticle does the charge screening job of an electron wave. It can be coerced into resonant oscillation. If the particle is conductive, like a carbon nanotube or nanodot, it can support surface plasmon polariton oscillations, and perhaps phonon oscillations.

The process is usually indirect, and several simultaneous processes are involved. Neutrons are formed as a first step, as a proton interacts with one of the electrons of a (resonant) electron wave (see Table 1-4, or with a dust particle, Table 1-5).

Fine wire mesh electrodes with high-frequency oscillations in ionized hydrogen are also active nuclear environments. Electron waves serve as charge shields; the problem is to have high charge density and frequent electron waves, or highly charged dust particles. This is the reason that even amateur experimenters stumbled onto various LENR reactions, without having any idea what was going on.

The elements of the puzzle were completed only as late as the early 21st century, where the background knowledge about electron density waves (polaritons, plasmons, dusty plasma) emerged with nanotechnology. By then, the isolated and partially disclosed inventions of Part 1 were forgotten. The mindset of a young aspiring researcher in nuclear physics is focused on high-energy, two-body interactions. Emerging charge waves or low energy charged dust particles are unheard "alien ideas." They are not only off the mainstream fusion research, but even outside the ideas of the small group of researchers on emergent nonlinear phenomena, like soliton waves.

Moray sought the help of contemporary scientists like Robert Millikan, Harvey Fletcher from Bell Labs, or Henry Eyring in vain. Tesla was too proud and hurt to talk to them. Thus both of them speculated that they found the energy of the oscillating Universe, a rather vogue notion. The very concepts of charge shielding to reduce Coulomb repulsion was a useless idea then, because the concept of fusion was not yet born when they demonstrated their inventions.

Table 2. The challenge of overcoming Coulomb repulsion.

	Mainstream	Off Mainstream	Off-Off Mainstream	Off^3 Mainstream
Theoretical Framework	Two-body D - T interactions; high temperature (thermonuclear).	Multi-body D - T interaction with weak charge screening and resonance.	Multi-body D - D interactions with mild charge and effective mass coupling	Multi-body e + p interactions with strongly localized mass and charge coupling
Usual Technical Solutions	Extreme heating inertial or magnetic confinement to satisfy the Lawson criteria.	Bussard Polywell, Farnsworth-Hirsch resonant heating. Interaction of a large volume of smeared electron cloud and deuteron cloud.	Classic Pons-Fleischmann: deuterated Pa lattice, DC current supply. Better versions: Patterson. Even better: Preparata, Scaramuzzi, Arata & Zhang, Rossi, Piantelli	See Part 1. Quasi-particle dominated territory + resonances. Local neutron production is dominant.
Result	Unsolvable for technical reasons, mainly for turbulent losses, troubles of tritium supply break-even impossible.	Sign of efficiency, maybe somewhere around break-even. Not portable, possible mass production, but not economic.	Sometimes better than break-even, even self-sustaining, unreliable due to quality control, not portable. Not suitable for mass production	Reliable, self- powered, several historical examples. Small, inexpensive units, portable devices Economic, suitable for mass production
Cost of Research So Far	≈ $200\text{-}300 \cdot 10^9$\$	≈ $50 \cdot 10^6$\$	≈ $50 \cdot 10^6$\$	≈ $50 \cdot 10^6$\$
	HOT FUSION		LOW ENERGY NUCLEAR REACTIONS	

They were truly ahead of their (and our) time.

But today, the details are clearer and fit together. There is a rich variety of possible LENR solutions and nuclear processes.

Charged dust particles are so perfect for charge shielding and so easy to create, that they even do well for the transmutation of heavy elements. The penetration of Coulomb barrier is technically uneconomical by other means, *e.g.* heavy ion collisions (see Table 1, Quantum Rabbit experiments, by E. Esko).

Fano Resonances

Readers familiar with the intricate details of oscillators may find the models in Figure 1 are oversimplified, a sort of linear "one mass, one spring" one tuned excitation frequency. Indeed, for plasmon polaritons, the oscillations are coupled ones, because incoming transversal infrared waves (or very sharp current pulses) might be the driving source. Moreover, it is a parametric coupled oscillation because the coupling electric field and plasma density do not depend solely on the power and frequency of the driving force. Heat generated during an LENR process during an oscillation (as shown in Figure 2) makes the system strongly nonlinear, and parametrically coupled. These systems can be driven into resonance at various frequencies, including both subharmonics and at much higher harmonics. Their resonant peaks are unique. They can be quite asymmetric and sharp, but sometimes rather broad, like the Fermi Ulam Pasta chains. One test result will be shown by Letts, Cravens and Hagelstein in Part 3.

These systems are fairly widespread in classical and quantum mechanics. They are termed "Fano resonances," commemorating Ugo Fano, who won a Nobel Prize for this interesting discovery.

The same applies to dusty (crystal) plasma resonances, shown schematically in Figure 3, where three major energy absorbing participants are shown: the electron cloud, the positive and negative ions, and the nanoparticles (see the review article by A. Mirosnichenko *et al.*, *Review of Modern Physics*, Vol. 82, July-September 2010, pp. 2257).

It is not a direct help for inventors and developers. It just outlines how strange, sharp resonances crop up all of a sudden seemingly out of nothing (see Figures 7, 8, 9).

Indeed, all the inventions mentioned in Part 1 contain a kind of Fano resonance, started just as lucky resonant effects observed by a prepared mind, like Tesla or Moray, etc. Some background information would help researchers of LENR to improve their engineering set-ups. Otherwise only luck helps.

Do we have to wait another hundred years when a teenage boy in the deserts of South Sudan, Ethiopia, Namibia or Mongolia will tinker again with the crystal detector radio of a long wave radio? Or can we learn from the lessons of forgotten inventions?

Luck is essential in science; we shouldn't be ashamed of it. In fact, these coupled parametric resonances are so complicated that it is impossible to build a good fusion reactor top-down, starting from scratch, with only theory at hand. It is futile to devise a good reactor just by listening to the theoretical lectures of famous professors of physics, like Feynmann, who blew up Papp's engine.

Though there are many open issues, rapidly developing nanotechnology is immensely helpful. Diagnostic tools are ready, and methods to grow and shape optimum nanoscale objects are improving. Nanotechnologists can help LENR because they want to prove their value and to increase their reputations. H-bomb designers had this opportunity 60 odd years ago and failed.

Certainly, a firm grasp of technology and theory would help the embattled LENR researchers, so we have to answer some questions before we are taken seriously.

Summing up the different methods by charge shielding by pseudo-particles, we have seen five major groups. They are listed by their method, the first known discoverer and the tentative date:

1) Resonant nanodust plasma (Tesla, 1890s)
2) Resonant nanocavities and plasma (Moray, 1920s)
3) Rare gas collision chain & chlorine (Papp, 1960s)
4) Needle tip amplification in plasma (Shoulders, 1980s)
5) High effective mass electron clusters with light or deuterated hydrogen metal lattice, electrolysis (Patterson, Mizuno, Pons & Fleischmann, 1990s, etc.)

Though these categories are subjective, they show that LENR processes are of wider scopes both in depth of time and physical formation than previously thought. Most probably the list is not complete. Each of these methods has advantages and drawbacks, summarized in Part 3. In general all are worthy of intensive study. (All the details are complicated and foggy.) All of their physical processes are more complicated then the simple high-energy two-body D - T collision processes.

The extra theoretical difficulties of charge shielding by pseudo-particles must be weighed against the gain of achieving its technical implementation. Further, better sub-categories and engineering ideas might emerge after intensive R&D efforts.

The identification of positive feedback loops for amplitude amplifications of coupled parametric resonant processes are quite a challenge, a nice task for open-eyed scientists. Though the roots of the LENR phenomena are very much older than the research of the 1990s, the historic role of Pons and Fleischmann is indisputable because all other attempts to establish this field have failed.

There are still a number of theoretical and technical questions to be answered, like:

• Are there direct $p^+ + e...e + p^+$ reactions (e...e notes the high effective mass electron cloud, regardless of its appearance as a surface wave or embedded in a solid nano particle)?
• Are poly-neutrons formed, and when and how many of them can exist?
• Are mass spectrometers proper tools to observe them?
• Are the present (mainstream) concepts of the nucleus and the atom good enough to deal with these not-so-new phenomena?

My tentative answer is that there are entirely new classes of interactions due to the possible appearance of poly-neutrons. Entirely new types of material may appear due to their neutron-rich nuclei. Therefore, present nuclear models may not always be usable. Moreover, two-body interactions lose their dominance; clouds of light nuclei may interact with clouds of electrons. These interactions are better treated by quasi-particle interactions as a distinctively different framework from two-body interactions. In this new arena, the fusion of medium sized nuclei—such as C, O, N—is possible at a very low energy level (of a few electron volts) at economic levels. Iwamura *et. al.* have solved this problem on a much smaller scale (U.S. patent application 0080903/2002).

The indoctrination level of this whole field is excessive. Only a number of mass-produced devices will change the present tragic situation. The present mainstream fusion is doubly cursed. The challenge is clear—to overcome the Coulomb barrier. However, the theoretical mainstream model is simply wrong: "dumb muscle" (thermonuclear). The technical solution for this erroneous theoretical answer is even worse; no resonance is used in any mainstream confinement-based solution (see Table 2).

This 50+ years of resistance to clear thinking in physics and engineering and biased intellectual property policy has already had devastating results in all aspects of our life on planet Earth.

It should be obvious by now to anybody with some technical background. Mainstream thermonuclear fusion is the wrong technical solution for the wrong theoretical framework (see Table 2 for a concise summary). At present it is too big to fail; it is driven not by results, but by the inertia of inter-government committees.

About the Author

George Egely graduated from the Technical University of Budapest (1973). He worked at the Nuclear Energy Research Lab of the Hungarian Academy of Science from 1974 to 1990. He was a guest researcher at CISE (Italy) in 1977 for three months, and at Brookhaven National Lab (U.S.) in 1981-82 for 16 months. He received his Ph.D. in 1982, on the subject of nuclear accidents of pressurized water reactors. Egely has compiled a large collection of ball lightning observations by eyewitnesses, and published a couple of semi-popular books on this subject. He is the author of three textbooks on the physics of "lost or forgotten" effects and inventions, and of several semi-popular books on the same subjects (in Hungarian). Since 1990 he has been a team leader in several small projects in alternative technologies. Some videos of these tests are posted online: www.greentechinfo.eu

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