Account of Cold Fusion by Screening and Harmonic oscillator resonance.

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Abstract

A model of cold fusion process is proposed. It is based on earlier fusion reaction rate calculations, assuming electron accumulation around two colliding deuterons, and using a specific relationship between the parameters characterizing the non-thermonuclear process. In this paper this model is completed, making the hypothesis of harmonic oscillators on particle level. Those harmonic oscillators make deuterons quasi-free in some circumstances, for example when a high level fast transitory current is decreasing. This combined model reveals a good agreement with some unclaimed as being cold fusion experiments, of fast high voltage high transitory currents through deuterated media. It is particularly shown that this model accounts for a growth of fusion rate, varying like the tenth power of the peak current. $10^n$.

1. Introduction

The model which is presented in this paper is the consequence of the non-dependence on the medium which cold fusion seems to have. It has been shown two years ago that D-D fusion reactions could occur by crossing of the lowered Coulomb barrier between deuterons, the possibility of this lowering being due to what was called "Double screening" [1][2]. This expression is not however very demonstrative of Coulomb barrier lowering process, which is essentially due to an electron accumulation around two deuterons, which are approaching at a distance of the order of the Bohr atom radius. So it seems more judicious to call this process "Nuclear Fusion by electron accumulation".

Being drastically different from the thermonuclear one, the correct description of this process on the macroscopic level, needs also a dimensional relationship between the physical variables, completely different from the one which is inferred from the Lawson criterion [2][3].

In fact this model, using only the electron accumulation concept, does not describe completely the physical process. It does exist a necessary macroscopic cause for triggering the microscopic process of electrons accumulation and tunneling through the Coulomb barrier. It has been shown in the reference [2] that the possibility of the microscopic process was in agreement with a quasi-free status of ions, space distributed according the Poisson law. It seems, at first sight, to be contradictory with the existing Coulomb forces. Thus there is matter to answer the question, in what circumstances the medium could be considered as being reduced to an quasi free ions set. An hypothesis on the possible cause is in fact suggested by experiments consisting to let flowing high and fast transitory currents through...
deuterated media. As it is shown it implies a plasma modeling by a set of harmonic oscillator.

According to this hypothesis, fusion reactions are the consequence of resonating harmonic oscillators, on the particle level, as much as of the electron accumulation phenomenon. A clue showing the underlying reality of such oscillators, comes from observations made by Lochte-Holtgreven at Kiel (Germany) during the seventies [4] [5], and Sethian et Al at NRL during the eighties [6]: neutrons are detected immediately when the current stops to grow (Figures 1&2).

In Kiel experiments, the neutrons production occured only during the decrease of a relatively moderate peak current of the order of $2 \times 10^4$ A, flowing in a capillary tube filled with Li($ND_3)_4$. The nuclear reactions producing those neutrons were called pycknonuclear by Lochte-Holtgreven, who used a term useful in Astrophysics, build on a greek root ($\text{πυκνό} = \text{dense}$) [7]. It means that there would be collective effects in nuclear reactions occurring in dense media, which would modify the accustomed rate, known by ion collisions in accelerators. The proposed model of "Nuclear Fusion by electron accumulation", joined to the harmonic oscillator hypothesis, is a tentative modeling of the pycknonuclear process. Suggested by observing the neutron production only from the current peak, it is shown that such a model is in fact in agreement with the experimental rates of change of the neutron production, in function of the peak current, observed at NRL.

2. General delineation of the two process model: electron accumulation and harmonic oscillator resonance.

2.1. Harmonic oscillator resonances suggested by experiments.

One can assume that the ion and electron distributions are uniform during the growing current phase, as there are no produced neutrons during this phase. This no neutron production has been observed at Kiel University and at NRL using effective short current pulse, that is whose duration was typically between 100 ns and 300 ns (figure 1). During the growing phase, the medium is more and more ionized, and above all, is ruled by Coulomb forces. One has also to mention that, although the medium is gaining much energy, in different amounts according to the experiment, the thermal turbulence of the ions is too low to qualify it as being "thermonuclear".

In Kiel experiments the ringing frequency of the capacitor bank was rather low, typically 200 KHz, but the current pattern was reshaped by a plasma instability, one can attribute to Ampère force: the effective peak current, it means the one which was correlated with the onset of neutron production was typically reached in some hundred of nanoseconds, according the diameter of the cylindrical deuterated medium, which was contained in a glass capillary pipe. The deuterated medium was almost completely ionized at the peak current, which was $2 \times 10^4$ A, according to the [4] reference. The capacitor bank voltage was chosen to get an approximate voltage gradient of 30kV/cm. Given the relatively low peak current, the neutron rate was relatively moderate.
Figure 1: Figure from reference [5] showing that, in the Kiel experiments, the neutron burst occurred during the current decrease.

In NLR experiments, published in 1987 [6], a current pulse of typically 120 ns growing time, was flowing in a frozen deuterium fiber whose initial diameter was 125-μm. The growth of the observed neutron burst in function of the peak current I (Maximum value: 640 kA), and beginning just at this peak (Figure 2), was claimed close to $10^{10}$ (Figure 3). But the experimenters had some problem in detector calibration, so this mishap gave a rather great indetermination of the absolute rate of the neutron burst. After the first estimate of $8.4 \times 10^{11}$ neutrons, this rate had to be divided approximately by a hundred factor [6]. But this is in fact unimportant given that the $10^{10}$ growth has not been questioned. As it is shown further this result is in agreement with the model of Fusion by electron accumulation, and harmonic resonance, in the limits of experimental and calculations precision.

![Figure 2](image-url) - Figures from reference [6]. The fast onset of the neutron burst is clearly coincident with the current maximum. It appears on this second figure that this onset begins slowly just before the current maximum, but the rate becomes much faster at this maximum. The collective movement of the ions, taken into account in reference (1), is unimportant for the fusion reaction production, in comparison with the harmonic oscillations on deuteron level. This phenomenon plays a role of deuteron quasi-accelerator.
Figure 3. From reference [6]. The neutron number per current burst, in function of peak current, for an 80 \( \mu \)m initial diameter of the frozen deuterium fiber. The authors have given a fit to the power law \( Y=7.3 \times 10^{10} \) (I in Mega-Ampère).

But one has to take into account other results from NRL, obtained with different experimental conditions. In those experiments, the current was typically higher i.e. 800 kA, but the growing time was longer, i.e. 800 ns [8]. As well as a neutron production beginning at the current peak, other neutron bursts were observed, before and after the peak, for approximately 400 kA (Figure 4). The neutron production, in function of the peak current, was not varying approximately like \( I^{10} \), but like \( I^{15} \) (Figure 5).

There are essential differences between the Kiel and NRL experiments. Firstly there was a containment in Kiel experiments during the neutron production phase, but no containment in the NRL case. Secondly the amounts of energy introduced into the medium during the growing phase are very different. By the way one has to emphasize on the fact that just a few of experimental results are useful for the problem which is by now taken into account. The majority of high voltage capacitor discharges into deuterated media, performed since the fifties have been realized with the background idea to get "thermonuclear conditions". So the experimenters have too often realized experiments with too long ringing periods (at least some microseconds), and they missed the informative measurements: peak current and neutron burst in function of time. Experimenting in this way, it is easy to conclude falsely, for example like in reference [10], that the neutron burst vary like \( I^4 \).

One has also to mention other experiments, performed also at NRL, which consisted of using again a short current pulse, whose full width at mean current value was 80 ns, with a some hundred kilo-Ampere peak [9]. The structure of the medium was different, called X-pinch by the experimenters, who aimed at first to get X-rays. Nevertheless a supplementary information was given, comparatively to the other experiments: simultaneous the voltage and the current were measured.
simultaneously in function of time, so the energy delivered to the medium is better known than in the other cases, where it can only be estimated (Table 1).

![Graph showing current, dl/dt, X-rays, and neutrons](image)

**Figure 4** From the reference [8], showing for a long current pattern, the most essential physical variables I, dl/dt, X-rays, neutron burst.

Apparently the behaviour of the deuterated medium is the same for 10 kJ/cm³ and for 50 MJ/cm³: neutron production occurs only when the current begins to decrease (Table 1). The current decrease is the cause of the instability formation, revealed by "beads" on X-pictures: this is the case in the Lochte-Holtgreven experiments performed in Kiel [4] [5], and in the J.D.Sethian experiments performed at NRL [6]. But in another experiments, the cause of instabilities is apparently the excess energy afforded to the medium, typically some hundreds of MJ/cm³: this is the case observed by K.C.Mittal et Al [9].

In both cases, a magnetohydrodynamic instability can occur, no matter which is its cause. (In the Kiel experiments the primary cause can be attributed to the "Ampère force"). But also in both cases, i.e. fast current decrease or magnetohydrodynamic instability the electron accumulation process can occur consecutively to a cause making the deuterons quasi-free. The matter is now to examine in which extent the harmonic oscillator hypothesis is realistic.
Figure 5 From reference [8]. The current growth is slow, in comparison with the one of Kiel experiments, or with the one of NRL experiments performed in 1987. The medium is frozen deuterium, whereas Li(ND₃)₄ was used in Kiel experiments. Neutrons and X ray bursts come out not only from current maximum, but also before and after this maximum. A fit to a power law was given: Y=(3.9x10⁻⁶)₁⁵, with I in kA.

2.2. Essential of the electron accumulation model.

It consisted to assume for the potential between two deuterons a semi-phenomenological expression  \( U(r) \), containing the most important, that is the exponential. This exponential shape of screened potential is justified both by experimental results and theoretical calculations [16] [17]. The polynomial terms \( (r-a) \) and \( (r-b) \) were supposed to take into account the extra electron density approximately at a Bohr radius distance from the nucleus, and the term \( (e/r-V_p) \) takes into account the change of reference level due to electron charge depopulation around the two colliding deuterons. The term \( V_p \) is equal to the sum of the Coulomb positive potentials created by electron depopulation around the two colliding deuterons and its existence is grounded on more general considerations about the electromagnetic gauge [18].

\[
U(r) = e(e/r-V_p) (r-a)(r-b) \exp(-kr)
\]

The predominant terms were recognised as being the exponential one and the so called "Pedestal potential" \( V_p \). The a and b parameters are due to the electron
accumulation, and the results were robust relatively to any changes of the \(a, b, V_p\) parameters.

### Table 1

The most important parameters characterizing the Kiel and NRL experiments.

<table>
<thead>
<tr>
<th>Leading edge duration (second)</th>
<th>Voltage (Volt)</th>
<th>Current at the onset of the neutron burst (Amps)</th>
<th>Current density at the current apex, for the initial neutron burst of the medium (\text{A/m}^2)</th>
<th>Injected energy into the medium at the neutron burst onset (kJ)</th>
<th>Injected energy density at the neutron burst onset (\text{MJ/cm}^3)</th>
<th>Number of neutrons per current impulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiel 1974</td>
<td>(5 \times 10^{-7})</td>
<td>(3 \times 10^5)</td>
<td>(3 \times 10^4)</td>
<td>(2 \times 10^6)</td>
<td>(0.6)</td>
<td>(10^2)</td>
</tr>
<tr>
<td>NRL87</td>
<td>(1 \times 10^{-7})</td>
<td>(5 \times 10^5)</td>
<td>(5 \times 10^5)</td>
<td>(4 \times 10^7)</td>
<td>(30)</td>
<td>50</td>
</tr>
<tr>
<td>NRL90</td>
<td>(8 \times 10^{-7})</td>
<td>(5 \times 10^6)</td>
<td>(2 \times 10^5)</td>
<td>(10^2)</td>
<td>(400)</td>
<td>(10^8)</td>
</tr>
<tr>
<td>NRL91</td>
<td>(8 \times 10^{-6})</td>
<td>(1.4 \times 10^6)</td>
<td>(2.5 \times 10^5)</td>
<td>(10^2)</td>
<td>(1.3 \times 10^2)</td>
<td>(4.5 \times 10^8)</td>
</tr>
</tbody>
</table>

The second item was the introduction of a new relationship between the nuclear reaction rate \(R\), the Coulomb barrier crossing rate \(F\), the barrier width \(L\), the barrier crossing time \(\theta\), \(n\) being the number of nuclei which could be involved in nuclear fusion reactions, and \(\sigma\) the nuclear cross section:

\[
R = \frac{1}{4} n^2 \sigma F L/\theta
\]  

The introduction of this formula was estimated as necessary, given that the Schrödinger equation showed clearly that using only deuteron velocity, like in the accustomed formula deduced from the Lawson criterion, was inconsistent in the case of low velocities and electron accumulation process [2] [3].

The results of calculations using early results given by Feodorovich [16] have shown, for a constant couple \((k, V_p)\), that is for a constant number of accumulated electrons around the two colliding deuterons, the logarithm of the reaction rate \(R\) was a linear relation of logarithm of the incident deuteron energy [2]. Typical results are showed on figure 6. The slope \(p\) of the straight lines is bounded by two approximative limits: 1.4 and 2. Those values are typical of a fractal dimension. But one has to emphasize on the fact that the exact number of electrons around the two deuterons, corresponding to each straight lines, is not known, and would necessitate important specific calculations which have not been possible to perform at this time.
Approximate values were given for this number, assuming that all electrons were confined in a sphere whose radius was the one of Bohr, but that is rather approximate, inspite there was concordance with the stochastic point of view. The stochastic theory gives in fact in a simple way the order of range of this electron number, which seems to be mostly in the range of $10^3$ to $2 \times 10^6$. This electron number corresponds to a p-value in the medium range, that is around 1.6-1.7. The stochastic point of view consists of assuming that deuterons are not submitted to any force, that is they are quasi-free in space, and that their space distribution obeys a Poisson distribution. Nevertheless, as it is shown below, the most important result which is numerically in agreement with experiments, is the existence of the straight lines and of their p-slope values.

3. The two ways of putting the medium into condition.

3.1 The medium is put into condition by energy excess.

In all cases where the way of getting the medium into condition consists of using an electric current, the final deuteron velocity, reached by electrodynamic interactions, is proportional to the square of r.m.s. current, obtained by integration between the onset and the peak. For similar current waves differing only by the peak, the deuteron energy is practically proportional to the fourth power of the peak current:

$$\frac{E'}{E} = \left(\frac{l'}{l}\right)^4$$  \hspace{1cm} (3)$$

The fusion reaction rate $R$ is obtained by using the results of Coulomb barrier crossing by electron accumulation. For a specific number of accumulated electrons, and for a constant number $n$ of deuterons which can be involved in the process, the logarithm of this rate $R$ follows a linear relationship in function of the energy logarithm $\log E$ [2], $p$ being the slope of this linear relationship:

$$\frac{\log R'}{\log R} = p$$

$$\frac{\log E'}{\log E} = (\frac{l'}{l})^{4p}$$  \hspace{1cm} (4)$$

Using (1), one gets:

$$R'/R = (l'/l)^{4p}$$  \hspace{1cm} (5)$$

The calculation of barrier crossing provides a p value which is bounded by two approximative limits:

$$1.4 < p < 2$$

Replacing $p$ successively by the two limits one gets a $R'/R$ variation between $(l'/l)^{5.6}$ and $(l'/l)^9$. But one has to remark that the lower limit corresponds to a greater number of accumulated electrons than the higher limit. In a dense medium the accumulated electron number would be lower than in a more diluted one, simply because electrons have a greater mean free path in a diluted than in a more dense medium. As the experimental result $l^5$ was obtained in a plasma which has been
heated during a relatively long time [9], its expansion was relatively important, and it is logical to consider the lowest limit of p. Given that apparently this value was given for “typical”, the corresponding p-slope could be as low as 1.25. Taking into account the uncertainty about the real number of accumulated electrons and consequently the p-value, there is an agreement between the experimental results and the electron accumulation model.

In this case the harmonic oscillator resonance hypothesis is not useful. To understand more completely the process it would be necessary to describe more completely the chaotic phenomenon generated by the excess energy, which contributes to make quasi-free deuterons.

3.2 The medium is put into condition by a fast current decrease.

In the case of fast current decrease, the modeling of quasi-free behaviour of the deuterons takes into account the resonance phenomenon at the particle level. One can describe simply the link between the pattern of electrodynamic force in function of time and the behaviour of the harmonic oscillator. What is an harmonic oscillator constituted of? We make the hypothesis that is is constituted of one ion and of the electrons which are in its near proximity. Those electrons having a relatively great velocity, there is no electron structurally associated with one deuteron to build one harmonic oscillator. It is sufficient to develop a non quantum picture. The return strength $\Delta F$ acting on the deuteron is the difference between two Coulomb forces, each being multiplied by a coefficient $k$. Assuming also the isotropy of electron distribution, this coefficient $k$ will be the same on both sides:

$$\Delta F = \frac{(kq)^2 - 2(kq)^2}{r^2} \frac{\Delta r}{r^2} \frac{\Delta r}{r^3}$$

(6)

This model is very close to "One composant plasma model", which consists of assuming that the plasma is made of one species of charged particles, flooded in a uniform medium of neutralizing charges [14]. A mono-dimensional description of the deuteron movement is sufficient for accounting the resonance phenomenon. $m$ being its mass, $q$ the elementary charge, $r$ the mean distance between the deuteron and its neighbouring electrons:

$$m \Delta r'' + 2(kq)^2/r^3 \Delta r = 0$$

(7)

And the own pulsation of the oscillator:

$$\Omega = \sqrt[2]{(2(kq)^2/mr^3)}$$

(8)

One can give a more complete description, for taking into account the interaction between harmonic oscillators. Classically, remaining in unidimensional case, the strength exerted on the oscillator $n$ by the oscillators $(n+1)$ and $(n-1)$, is function of the specific pulsation $\Omega$ of the $n$ oscillator and also of a coupling term $\Omega_1$:

$$F_n = -m \Omega^2 x_n - m \Omega_1^2(x_n - x_{n+1}) - m \Omega_1^2(x_n - x_{n-1})$$

(9)

The movement equation is thus:
\[ \frac{d^2x}{dt^2} = -\Omega^2 x_n(t) + \Omega^2(2x_n(t) - x_{n+1}(t) - x_{n-1}(t)) \]  

(10)

Changing the variable and using the mean distance \( l \) between harmonic oscillators:

\[ u(k,t) = \sum_{n=-\infty}^{+\infty} x_n(t) e^{-i kl} \]  

(11)

So the equation has the same shape than the initial one (7):

\[ \frac{d^2}{dt^2} u(k,t) = -\left[ 2 \Omega^2 + \Omega_1^2 \left( 2 - e^{ikl} - e^{-ikl} \right) \right] u(k,l) \]  

(12)

All oscillators have resonance pulsations between two limits, depending on the mean distance between two oscillators. This interval is analog to the one of the Brillouin zone, used in Solid state Physics [12].

It is interesting to mention the link that this model could have with a natural phenomenon which has been puzzling the scientific community for two centuries, i.e. the "Ball Lightning". Without discussing this phenomenon from an experimental point of view it is interesting to remark simply that the macroscopic balance of an harmonic oscillator set is possible, only in a spherical geometry. One can assume that the low amplitude oscillator movement is along the sphere radius. Given the spherical symmetry, the sum of the forces, acting perpendicularly to the sphere radius on a particular harmonic oscillator, and due to the other oscillators, is equal to zero. Such a phenomenon is observable as much during a thunderstorm, as well when a high voltage capacitor discharges into a dense medium. Many experiments have been performed during the last years, showing that brilliant long-living objects are formed at the time of a dense aqueous low temperature plasma collapses [15]. According the testimony of many observers, the ionized spherical structure is apparently soon destroyed by a light mechanical hurt, against a solid structure. The role of this mechanical hurt must be compared with the fast current decrease in an experiment like those of Kiel or NRL. It seems possible that there could be a link between the mechanical hurt which destroys a ball lightning and the premature current interruption in experiments of the Kiel type. the premature interruption being prompted partly by the hydrodynamic instability, caused by Ampère Force, and partly by the mechanical hurt; some specific experiments could let to conclude. It seems possible that this mechanical containment could favour the instability occurrence. The mechanical hurt or the fast current decrease produces a chaos status.

3.3. Numerical values.

During the current leading edge, and for a typical medium density of the order of \( 10^{23} \) particles per \( \text{cm}^3 \), the mean distance between two deuterons is in the \( 10^{-8} \) cm range. One can assume that, without electron accumulation phenomenon, those electrons are equally distributed in space. Without any electron excess in the medium, the number of electrons around one deuteron is typically equal to 6, from a purely topological point of view. If one choose this figure for the electron number
aking part to the non resonating harmonic oscillator's operation, so \( k=3 \) and with \( n=34 \times 10^{-24} \) g, one gets:

\[ \Omega = 1.44 \times 10^{14} \text{ rad/s} \]

In many high peak transitory currents experiments, performed in a deuterated medium, this medium is rich in electrons; this is exactly the case in Kiel experiments, where a compound of Lithium with heavy ammonium \( \text{Li(ND}_3)_4 \) was used, or in some NRL experiments where deuterated fibers were used. Given the uncertainty about the electron number, which takes part to the harmonic oscillator operation, it is in fact possible to ascertain only that \( \Omega \) is typically of the order of \( 10^{14} \) rad/s. In the case where one deuteron is so close to another for initiating the collision and electron accumulation process, leading to nuclear reaction, is the model pertinent? The pulsation is much higher in this case, \( r \) being typically in the range of \( 10^{-9} \) cm, the electron number around the two deuterons being typically of the order of \( 1 \times 10^3 \) or \( 2 \times 10^3 \) \[2\]. With \( k=10^3 \), one gets:

\[ \Omega = 2.6 \times 10^{17} \text{ rad/s} \]

The pulsation would be about at least \( 10^3 \) times higher when two deuterons are approaching together. However this model does not seem useful during the collision phase, the Coulomb barrier crossing being described by the Schrödinger equation, and the deuteron energy, supplied to the deuteron by the electrodynamic forces, being supposed constant during this crossing.

3.4. Forced movement of the harmonic oscillator, caused by a fast transitory current.

The description is purely classical; the equation of the harmonic oscillator forced movement is simply:

\[ x'' + \Omega^2 x = (1/m) F(t) \]  \hspace{1cm} (13)

One can get an estimate of the velocity which is given to the ions by harmonic oscillation, if one uses a realistic phenomenological current pattern. In first approximation, sufficient for getting a general delineation of the process, a "sawtooth" pattern is useful for describing the current wave, as well for Kiel experiments, as for the ones of NRL. The leading edge is thus a linear function:

\[ F(t) = F_0 \quad 0 < t < \theta_0 \]  \hspace{1cm} (14)

Deuteron velocity, due to electrodynamic forces, is obtained by neglecting the electromagnetic waves propagation time in the inner part of the conduction canal:

\[ x' = \frac{F_0}{\Omega^2 \theta_0} \left( 1 - \cos \Omega t \right) \]  \hspace{1cm} (15)

The first term corresponds to the collective deuteron velocity directed toward the conduction canal's axis. The second term describes the periodic movement of the harmonic oscillator.
The trailing edge is represented by the second part of the saw-tooth:

\[ F(t) = F_0 \left( 1 - \frac{t - \theta_0}{\theta} \right) \quad \theta_0 < t < \theta_0 + \theta \]  

(16)

Thus the deuteron velocity, during the current decrease, depends on the current growing time \( \theta_0 \), and also on the decreasing time \( \theta \): this is a pure oscillatory process:

\[ v' = \frac{F_0}{m\Omega^2} \left\{ \left( \frac{1}{\theta_0} + \frac{1}{\theta} \right) \sin \Omega(t - \theta_0) - \sin \Omega t \right\} \]  

(17)

The strength, acting on the deuteron, is practically the Lorentz force, particularly for the maximum \( F_0 \):

\[ F_0 = q v_0 B \]  

(18)

\( v_0 \) being the medium collective velocity at the time of current maximum, corresponding to the maximum of the electrodynamic forces. At a specific point, located at the \( r \) distance from the axis, \( R \) being the radius of the conduction canal, one gets the induction \( B \) in function of the maximum current:

\[ B = \frac{\mu_0 I r}{2\pi R^2} \]  

(19)

Transfering the \( F_0 \) expression in function of the velocity \( V_0 \) and the induction \( B \), brings to the fore the velocity amplification, the maximum velocity \( v \) being:

\[ \nu = \frac{\mu_0 q v_0 I r}{m\Omega^2 2\pi R^2} \left( \frac{1}{\theta_0} + \frac{1}{\theta} \right) \]  

(20)

For a numerical evaluation, one can consider the point just in the middle between the axis and the periphery of the cylindrical conducting canal, that is \( r=R/2 \). One can thus introduce the velocity amplification factor \( f \), such as \( v = f v_0 \):

\[ f = \frac{\mu_0 q v_0 I}{m\Omega^2 4\pi R} \left( \frac{1}{\theta_0} + \frac{1}{\theta} \right) \]  

(21)

In comparison with the equation which rules the velocity during the current growth, the only difference is the change of the factor \( 1/\theta_0 \) into \( (\theta+\theta_0)/\theta_0 \). if the trailing edge is much shorter than the leading edge, its duration only rules the process. For a trailing edge duration \( \theta_0 \) equal to the leading edge duration \( \theta \), the maximum deuteron velocity during the resonance is early multiplied by the 2 factor. But a shorter trailing edge would give the possibility to get a more effective quasi-
accelerating effect of the deuteron. One has also to notice that the formula (14) cannot be compared completely with the (16) one, because the medium is only in its growing ionization phase, during the leading edge. In another terms F₀ has necessarily not the same value in (15) and (17) formulas. Nevertheless the deuteron velocity amplification does exist during the leading edge, but it becomes important to cause collisions leading to nuclear reactions by electron accumulation, only when the current stops to grow. The formula (20) suppose that the peak current is reached in a sufficiently long time, for getting a high ionization level: this is the case of the experiments related in references [4-6]

The maximum deuteron energy E, accelerated by resonance is thus proportional to \((v₀ I)^2\). Given that \(v₀\) is proportional to the square of peak current I, the deuteron energy is thus proportional to the sixth power of the peak current. In the case where this decreasing time \(θ\) is sufficiently short in comparison with the growing time \(θ₀\), the maximum deuteron energy is also inversely proportional to the square of the current decreasing time.

\[ E \approx I^6 θ^{-2} \] (22)

Like in the case where the medium is put into condition only by an excess of energy, one can get the nuclear reaction relative rate of variation, using the results of the nuclear reaction rate calculations [2], in function of energy, for a constant number of accumulated electrons, according to the (4) relation.

\[ \log \frac{R'}{R} = p [6 \log (I'/I) + 2 \log (θ'/θ)] \] (23)

Calculations give for the p-parameter a value which is bounded by 1.4 et 2, according to the number of electrons accumulated around the two colliding deuterons. On the figure 3, reproduced from reference [6], the slope of the regression straight line, summarizing the experimental results, seems in fact closer to 8.5, instead of the 10 value claimed by the authors. The corresponding p-parameter is thus 1.41, and the accumulated electron number is rather high. But if one accept the value of 10 which is proposed by the authors, then the p-parameter is equal to 1.66, which corresponds, according to the calculations, to a lower number of accumulated electrons around the two colliding deuterons.

\[ \frac{R'}{R} = (I'/I)^{10} \] (24)

What it is important is that the p-value, deduced from experimental results, is in the range of the Coulomb barrier calculations. But one has also to emphasize on the fact that those crossing barrier calculations have not yet been performed with sufficient matrice dimensions [2]. Given this fact, the concordance can be estimated rather good between calculation and experiment. The same experiments, performed with lithium dissolved in heavy ammonia would have probably given a different result, but the p-value would be slightly different, given that the outcome of the experiments depends of many parameters, for example the density of the medium, which was different in the the Kiel and NRL experiments.

The harmonic oscillator hypothesis putting the medium into condition on the particle scale, is thus validated by NRL experiments. One has also to remark that the
current density is relatively more important in the NRL experiments than in the Kiel experiments. This is an supplementary clue showing that the electron richness play a great role in the process.

4. Experimental representative points, in the (Log \( T/T_0 \), Log \( E/E_0 \)) diagram.

The current square integral can be supposed varying little, in first approximation, during the nuclear fusion reaction burst, as its duration is short in comparison with the current rising duration.

According the formula (20), the maximum deuteron velocity is achieved multiplying the velocity \( v_0 \) by the \( f \) factor. If one chooses, for example, the parameters of Kiel experiment, \( \Omega = 2 \times 10^4 \) A, \( \theta = 10^{-7} \) s, \( R = 0.05 \) cm, for a density of \( 10^{23} \) particles per cm\(^3\), and if one uses the pulsation of the elementary oscillator, according to (7), surrounded by an electron cloud, corresponding to an approach leading to a collision \( (\Omega = 1.44 \times 10^{14} \) rad/s), one gets a \( f \)-value in the \( 10^6 \) range. It could mean that the collective velocity at the apex should be multiplied by \( 10^6 \). It would contradictory, that such a corresponding energy on the deuteron level would imply an energy quantity largely greater than the density of 10 kJ/cm\(^3\), injected in Kiel experiments. The amplitude of the maximum deuteron displacement, gives more information. The deuteron maximum energy is then in the \( 10^2 \) eV range, corresponding to a maximum \( 10^7 \) cm/s velocity, and to an oscillation amplitude of the order of \( 3 \times 10^{-8} \) cm/s. So oscillation amplitude is of the order of the distance between deuterons, for \( 10^{23} \) particles per cm\(^3\). The resonance of harmonic oscillator, constituting the medium, prompts collisions between deuterons, and a certain amount of thermalisation, by inelastic collisions. The quoted maximum amplitude velocity is difficult to reach, given the high density of the medium. The rate of deuterons participating to an electron accumulation, before thermalization is a growing function of density. So medium operation, leading to collisions and electron accumulations can be considered as being ruled by the thermal deuteron energy (of the 0.6 eV order in the Kiel case) (Figure 6).

The thermal energy is also the good parameter in the case of case of NRL experiments performed in the eighties [6]. This energy is approximately \( 2.5 \times 10^3 \) times higher than in the Kiel experiments, that is approximately the ones obtained by cluster collisions in Brookhaven [19].

As for the \( Y \)-values, taking into account Helium 4 production rate which could be \( 10^5 \) to \( 10^6 \) times higher than the one of Helium 3 [11], the new representative point of Kiel is well apart from the one drew in the references [1] and [2], but it is nevertheless outside the thermonuclear range (Figure 6). For an neutron production rate, rectified approximately to \( 10^{10} \), the representative point of the NRL experiments performed during the eighties [6], is then a little above the Brookhaven point. With the parameter \( T \) proportional to \( R \) (such as \( T = \sigma F L/\theta \)), the Kiel and NRL points are close to a straight line in the diagram (Log \( T/T_0 \), Log \( E/E_0 \)), which could correspond approximately to a number of accumulated electrons between \( 1 \times 10^3 \) and \( 2 \times 10^3 \). However, as was shown before, it is not yet possible to put forward any more precise number.
Figure 6 Estimated position of the representative points for Kiel, NRL and also Brookhaven experiments, in the \((\log E/E_0, \log T/T_0)\) diagram, taking into account the harmonic oscillator resonance. The results of barrier crossing calculations, after correction due to a limited matrix dimension number, give straight lines for a constant screening couple \((k, V_0)\) \((2)\). \(k\) is given in \(\text{cm}^{-1}\) and \(V_0\) in volts:
\[
(3.22 \times 10^9 \text{ cm}^{-1}, 6.27 \times 10^2 \text{ volt}) - (3.78 \times 10^9 \text{ cm}^{-1}, 2.01 \times 10^3 \text{ volt}) - (5.81 \times 10^9 \text{ cm}^{-1}, 4.59 \times 10^3 \text{ volt}) - (1.38 \times 10^{10} \text{ cm}^{-1}, 5.91 \times 10^4 \text{ volt})
\]
Arc of curve D-D: thermonuclear process.

There is also another parameter which one would have to take into account, that is the possible dependence of the accumulated electron number on the medium density. Whatever would be the exact number of those accumulated electrons, their number is close to the one given by the stochastic model. The segment of straight line representing the specifically so called "cold fusion" experiments is obtained assuming the same high \(^{4}\text{He}\) number, as before. If one assumes also the electrodynamics forces effectiveness, which could be due to internal field transitories in the Palladium, and if one assume an \(f\) factor in the same range as before, one gets a segment of straight line, shifted toward higher energies and higher production rates, in comparison with \([1]\) et \([2]\) papers.
5. Conclusion

The correlations between theoretical calculations and experimental results give a greater consistency to the two points of view. Firstly it reinforces the NRL results which could have been looking as inexplicable. Secondly it reinforces the point of view of nuclear fusion by electron accumulation.

Given that all experiments have their place in the \((\log \frac{R}{R_0}, \log \frac{E}{E_0})T\) diagram, the experimental 15 and 110 laws give in fact a larger view on the cold fusion process. What is occurring while a fast current impulse is flowing in a deuterated medium, is really a cold fusion process. It is similar to the process which occurs during introduction of deuterium into Palladium, used as a substrate, whatever is the way of introducing this deuterium. In another words, this phenomenon is possible as much in a plasma, formed by introduction of deuterons into Palladium, used as a substrate, than in a plasma formed by high voltage, high current discharges. Macroscopically and experimentally the processes seem very different, but they are the same on particle level.

References

