Condensed Plasmoids – The Intermediate State of LENR

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Abstract

This document describes a new theory of LENR based on the experimental and theoretical findings of other researchers, such as Ken Shoulders [1], Edward H. Lewis [2], among others.

After decades of research on high-density charge clusters, ball lightning and LENR it turns out, that Edward H. Lewis was right with his hypothesis: Atoms can enter a previously unknown state of matter, in which they behave like ball lightning, and which is an intermediate state of the LENR reaction.

A quantum-mechanical model of this strange state of matter is provided by the author [3], which will in the following be called **"condensed plasmoids (CP)"**.

In contrast to the quantum-mechanical model of the atom, which is based on the spherically symmetric electrostatic potential of the nucleus, the quantum-mechanical model of CP is based on the cylindrical symmetry of a very thin and very dense plasma "wire".

In CP both, the nuclei and the electrons are moving rapidly in opposite directions along the plasma wire. This results in a strong electric current through the wire, pinching the plasma thin via its strong magnetic field.

The assumption, that the nuclei of the atoms are fixed points in space (Born-Oppenheimer approximation), is not adequate for modeling CP. The wave functions of all the electrons and all the nuclei are largely delocalized in one dimension.

The intrinsic magnetic field of CP leads to self-organization of their shape in complicated ways, minimizing their energy:
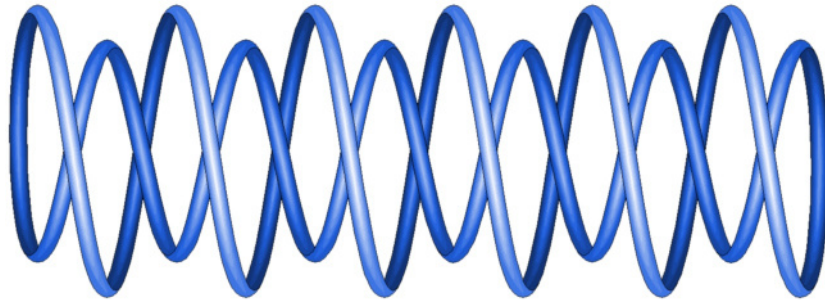
**Figure 1** Example of the self-organized shape of a condensed plasmoid

CP are extremely dense along one spatial dimension (much denser than ordinary matter). CP enable nuclear reactions between the ions via strong electronic screening of the Coulomb barrier.

The gamma radiation of nuclear reactions inside the plasma wire is suppressed, because the dense electron current in the plasma wire provides high dampening of the dipole oscillation of excited nuclei. This mechanism is analogous to a traveling-wave tube.

1. Experimental Evidence of CP in LENR experiments

Via thorough electron-microscopic analysis of Karabut's glow discharge cathodes I. Savvatimova and B. Rodinov have discovered a multitude of strange traces [2]:
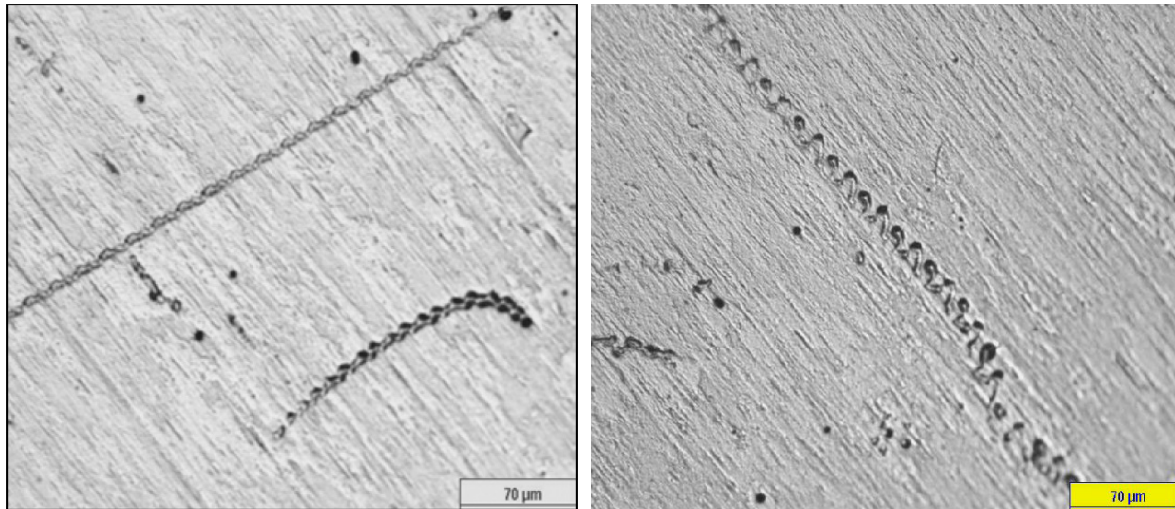

Figure 2   Strange traces discovered by I. Savvatimova and B. Rodinov at Pd cathodes

These traces can be understood by assuming they are caused by CP ionizing the surface of the metal.

There is experimental evidence from Savvatimova and independently from Urutskoev (later reproduced by C. Daviau et. al), that CP can reside for hours and days in the remains of Ti wire explosions in water. From these remains CP can emit as "strange radiations", which can leave peculiar traces at nuclear emulsions or X-Ray films brought in proximity to these remains:

Figure 3   Residual trail mark of a CP, I. Savvatimova and B. Rodinov
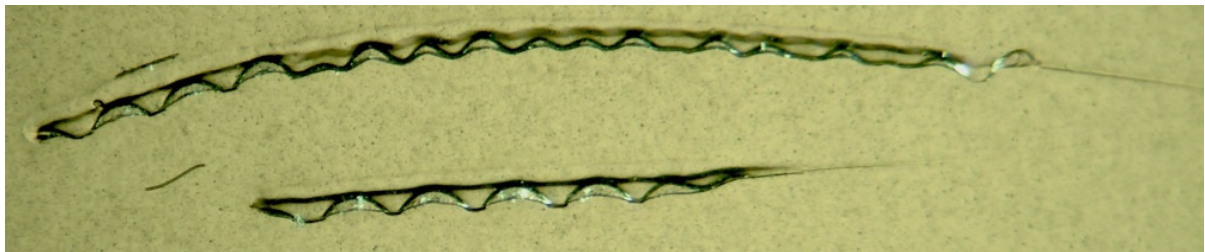
Figure 4   CP traces on X-ray film, presented at the EADS colloqium in 2010
by C. Daviau, D. Priem and G. Racineux, Ecole centrale de Nantes

The above image from Ecole centrale de Nantes has helped the author to understand, how CP self-organize from an originally linear form with open ends into a closed loop, where the intrinsic current flows back to the other end.

Also, a wealth of experimental information on CP has been collected by Ken Shoulders [1] under experimental conditions much different from typical LENR experiments:
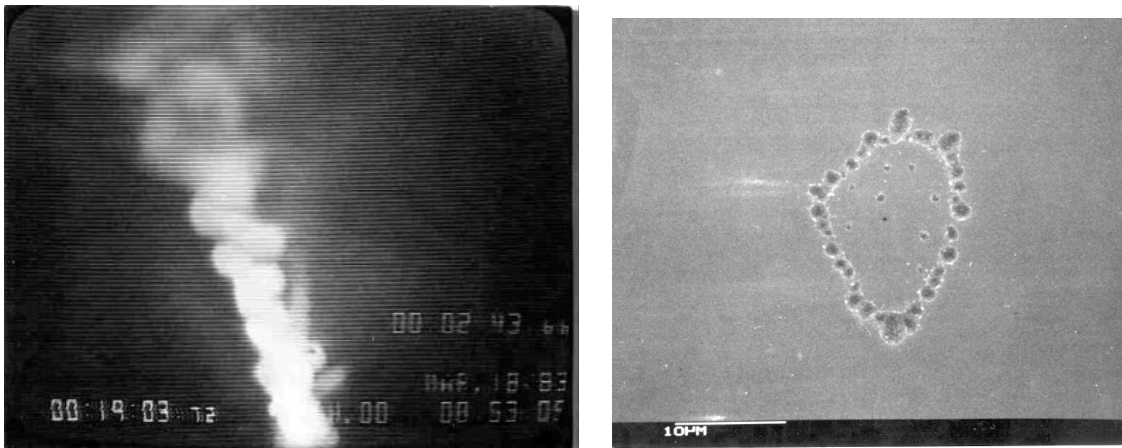

Figure 5   Left: Pinhole camera side view of CP in vacuum. The length of the CP is approximately 0.1 inches. Right: Impact of an accelerated CP on a target surface. Ken Shoulders [1]

It should be noted here, that the respective authors of the above experimental findings have drawn their own differing conclusions, on what the observed objects are. It is beyond the scope of this document to discuss the plausibility of these conclusions.

2.   The Cylindrical Model of CP

Modeling of CP is based on the following **basic assumptions**:

(1)   CP contain ensembles of atomic nuclei densely lined up in a very narrow channel.

(2)   The distances between the nuclei are so small, that all electrons bound to these nuclei are delocalized along the channel. In other words: Even in their electronic ground state CP don't consist of individual atoms. CP rather form a quasi-one-dimensional plasma.
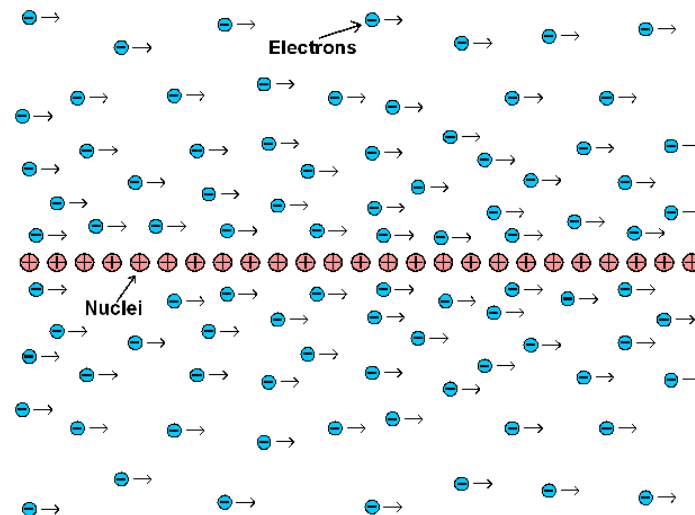
Figure 6   Basic model of a CP. The CP similarly extends to the left and to the right of this picture

The shape and quantum mechanical state of CP can be very complicated. In order to obtain a simple quantum mechanical description of CP, the following simplifications are used, which will subsequently be called "**the cylindrical model of CP**":

(3)   The CP are perfectly straight, i.e. they are not bent to rings, helices etc. The CP is oriented in parallel to the z-axis of the modeling coordinate system.

(4) Most electrons bound to a CP are moving in z-direction, i.e. an electric current is flowing in negative z-direction. This is the result of spontaneous symmetry breaking, which occurs during orbital occupation.

(5) The CP have length L and contain a total nuclear charge Q. Results will be analyzed for the limit $L \rightarrow \infty$ and $Q \rightarrow \infty$ with charge density L/Q being held constant.

(6) The electron wave functions of CP are confined in the interval $0 \leq z < L$. At $z = L$ these wave function are continuously extended to their value and gradient at $z = 0$, as if the CP were rings. However, this is meant to describe only the circular boundary condition of the wave functions at $z = L$, not the shape of the CP.

(7) No external field is applied to the CP.

(8) The positive charge of the nuclei is homogeneously distributed on the z axis. The width of the nuclear charge channel is infinitesimal thin. ("homogeneously charged, infinitely thin wire").

(9) The Born-Oppenheimer approximation is broken down for the z-direction, but is used for the x and y directions.

(10) For the purpose of computing the nuclear repulsion energy it is assumed that a CP contains two sorts of atomic nuclei with nuclear charges Z_1 and Z_2 in 50%-to-50% mixture. These charges are assumed to interleave along the z-axis. The total number of nuclei N is assumed to be $4n + 2$, with n being integer. It is assumed that the inter-nucleic distance d is uniform between all neighbor nuclei with $L = Nd$. Circular boundary conditions are assumed, i.e. the nucleus at position z is really the same (i.e. not merely of the same sort) as the nucleus at position $z+L$.

(11) The time-independent Schrödinger equation is used for modeling, thereby neglecting relativistic effects and the magnetic moments of electron spins and electron orbits. Clearly, the Dirac equation would be more adequate for modeling CP, because the characteristic electron velocities can approach the speed of light. However, the involved complexities of such approach are avoided here.

(12) Magnetic fields from nuclear spins and movements of the nuclei are neglected. This implies, that the electron wave functions are modeled in an inertial frame of reference, where the center of mass of all nuclei is at rest.

(13) The multi-electron system is approximated by computing a collection of one-electron orbitals, whereby each electron orbital is subjected to the mean electric potential and magnetic vector potential created by the total charge density and total current density of all other occupied orbitals and the nuclei. The Pauli exclusion principle is used for determining orbital occupations of the ground state. Exchange and correlation energies are neglected.

3. CP Quantum Mechanics

For reasons of space constraints this chapter represents merely a summary of the mathematics. A comprehensive version of this chapter can be found at [3].

In quantum mechanics a stationary multi-electron state is usually described by a wave function $\Psi(\vec{r}_1, \vec{r}_2, ... \vec{r}_N)$ satisfying the multi-electron time-independent Schrödinger equation:

$$(14) \quad \hat{H}\Psi = \left[\hat{T} + \overline{U} + \overline{V}\right]\Psi = \left[\sum_i^N \left(-\frac{\hbar^2}{2m_i}\nabla_i^2\right) + \sum_i^N \overline{U}(\vec{r}_i) + \sum_{i<j}^N \overline{V}(\vec{r}_i, \vec{r}_j)\right]\Psi = \overline{E}\Psi$$

where, for the N-electron system, $\hat{H}$ is the Hamiltonian, $\overline{E}$ is the total energy, $\hat{T}$ is the kinetic energy operator, $\overline{U}$ is the potential energy from the external field due to the positively charged nuclei, and $\overline{V}$ is the electron-electron interaction energy.

The multi-electron wave function $\Psi(\vec{r}_1, \vec{r}_2, \ldots \vec{r}_N)$ is usually formed by a Slater determinant to ensure anti-symmetry.

However, the number of electrons in a CP can exceed 10^{10}, which renders equation (14) and a Slater determinant entirely impractical to compute, because a program cannot handle equations with e.g. 10^{10} coordinates.

According to simplification (13) a rigorously simpler approach is used here for modeling CP, requiring only moderate compute power.

So, instead of using a multi-electron Schrödinger equation describing the pair-wise interaction between N electrons, the cylindrical model uses N **single-electron Schrödinger equations** describing an electron in the **mean potential** of all other electrons and of the nuclei:

$$(15) \quad \hat{H}\Psi_i(\vec{r}) = \left[\hat{T} + \overline{U} + \overline{V}\right]\Psi_i(\vec{r}) = \left[-\frac{\hbar^2}{2m_e}\nabla^2 + \overline{U}(\vec{r}) + \overline{V}(\vec{r})\right]\Psi_i(\vec{r}) = \overline{E}_i\Psi_i(\vec{r})$$

where, for the electron number i, $\overline{E}_i$ is the total energy of this electron and Ψ_i is the one-electron wave function ($\hat{H}$, $\hat{T}$, $\overline{U}$ and $\overline{V}$ as above).

Of course, this is merely an approximation. For example, the approach doesn't account for the exchange energy and the correlation energy usually deemed important in quantum chemistry.

At first glance this looks still challenging to compute, because there are N Schrödinger equations to solve. Fortunately, large numbers of these equations can be computed in groups, because they produce nearly the same charge density distributions and current density distributions.

In order to solve Schrödinger equations (15) approximately, the following **product ansatz** is made to factorize the wave function in cylindrical coordinates:

$$(16) \quad \Psi(\rho, \varphi, z) = \Psi_\rho(\rho)\Psi_\varphi(\varphi)\Psi_z(z)$$

The **axial factor** is solved by plain waves:

$$(17) \quad \Psi_z(z) = \sqrt{\frac{1}{L}}e^{ikz}$$

with the energy eigenvalues (measured in units of the Rydberg energy Ry):

$$(18) \quad E_z = a_0^2 k^2$$

Due to simplification (6) the energy eigenvalues are quantized to a discrete spectrum, because wave numbers k have to meet the following boundary condition:

$$(19) \quad k_l = l\frac{2\pi}{L}, \text{ where } l \in \mathbf{N}_0$$

The **azimuthal factor** is solved by:

$$(20) \quad \Psi_\varphi(\varphi) = \sqrt{\frac{1}{2\pi}}e^{im\varphi}, \text{ where } m \in \mathbf{Z}$$

with eigenvalues (in units of Ry times ρ^2):

$$(21) \quad E_\varphi = a_0^2 m^2$$

The substitutions $r \equiv \dfrac{\rho}{\rho_0}$ and $R_i(r) \equiv \rho_0 \Psi_i(\rho)$ are used in the following. The reference distance ρ_0 is defined as:

(22) $\quad \rho_0 = \dfrac{eL}{4Q}$, where e is the elementary charge, L is the length of the CP and Q is the total charge of all nuclei of the CP.

The **radial** factor of the Schrödinger equation (15) can be expressed as:

(23) $\quad r^2 R'' + rR' + \left\{ \left[E_{nm} - U(r) - V(r) \right] a^2 r^2 - m^2 \right\} R = 0$, where E_{nm} are the radial-azimuthal eigenvalues in Ry, $U(r)$ is the electron-nuclear interaction energy in Ry, $V(r)$ is the electron-electron interaction energy in Ry and $a = \rho_0 / a_0$ (a_0 being the Bohr radius).

The following **ansatz for the radial wave function R** is used:

(24) $\quad R = f(r) \cdot \exp(-\zeta r)$

Function $f(r)$ **is approximated by a polynomial**:

(25) $\quad f(r) \approx \displaystyle\sum_{j=0}^{J} c_j r^{m+j}$ for $\beta \in \mathbf{N}_0$ and $c_j \in \mathbf{R}$

The coefficients c_j have to meet the normalization criteria:

(26) $\quad 1 \equiv \displaystyle\sum_{k=0}^{J} \sum_{j=0}^{J} c_k c_j \frac{(2|m| + k + j + 1)!}{(2\zeta)^{2|m|+k+j+2}}$

The exponential scaling factor ζ in (24) computes as:

(27) $\quad \zeta = a\sqrt{-E_{nm}}$, where $E_{nm} < 0$ (because only bound states are modeled)

The potential energy $U(r) + V(r)$ **is also approximated by a polynomial**:

(28) $\quad U(r) + V(r, v_z) \approx \dfrac{1}{r} \displaystyle\sum_{p=0}^{P} b_p r^p$

An approximated solution to equation (23) can then be expressed by the **iterative formula** computing the coefficients from the value of c_0:

(29) $\quad c_j = \left(2|m| j + j^2 \right)^{-1} \left\{ \left[\zeta(2|m| + 2j - 1) + a^2 b_0 \right] c_{j-1} + a^2 \displaystyle\sum_{p=1}^{P} b_p c_{j-p-1} \right\}$,

where $c_i = 0$ for $i < 0$

Note, that the coefficients c_j are all proportional to each other.

The total **nuclear repulsion energy** (of all nuclei together) in units of Ry is:

(30) $\quad U_{nuc} = \dfrac{Q^2}{e^2} \dfrac{a_0}{L} \dfrac{8}{(Z_1 + Z_2)^2} \left[Z_1 Z_2 + \displaystyle\sum_{j=1}^{N/4} \left(\frac{Z_1^2}{4j} + \frac{Z_1 Z_2}{1 + 2j} + \frac{Z_2^2}{4j} \right) \right]$, where a_0 is the Bohr radius, L is the length of the CP, Q is the sum of all nuclear charges of the CP, e is the elementary charge, Z_1 and Z_2 are the charges of the two sorts of nuclei.

The **electron-nuclei interaction energy** (in units of Ry) is:

$$(31) \quad U(\rho) = \frac{1}{a}\ln(r) - U_0 \text{ , where } U_0 = \frac{4Qa_0}{eL}\ln\left(\frac{4Q}{e}\right)$$

The electron-electron interaction energy (in units of Ry) is:

$$(32) \quad V(r,v_z) = -V_0(v_z) - \frac{2a_0}{\pi L}\int_0^L \left\{\left[\sum_{i=1}^N |R_i(r')|^2\left(1 - \frac{v'_{z,i}v_z}{c^2}\right)\right]\int_0^{2\pi}\ln\sqrt{r'^2 - 2r'r\cos\varphi + r^2}\,d\varphi\right\}r'dr' ,$$

$$\text{where } V_0(v_z) = -\frac{2a_0}{\pi L}\int_0^L \left\{\left[\sum_{i=1}^N |R_i(r')|^2\left(1 - \frac{v'_{z,i}v_z}{c^2}\right)\right]\int_0^{2\pi}\ln\sqrt{r'^2 - 2r'\frac{L}{\rho_0}\cos\varphi + \frac{L^2}{\rho_0^2}}\,d\varphi\right\}r'dr' ,$$

N is the total number of electrons, c is the speed of light, v_z is the axial electron speed and φ is the azimuth.

The electron velocity can be computed by its axial quantum number l:

$$(33) \quad v_z == c\sqrt{1 - \left(2\pi^2\alpha^2 l^2\frac{a_0^2}{L^2} + 1\right)^{-2}} \text{ , where } \alpha \text{ is the fine-structure constant}$$

4. *Ab Initio* Simulations of CP and Numerical Results

Based on the theory above the author is undertaking *ab initio* (i.e. derived only from first principles) quantum-mechanical simulations of CPs. This is the subject of ongoing research. The goal is to obtain the quantitative properties of CP, such as its densities, intrinsic current and bonding energy.

The simulation tool and the computational results will be made available at the author's web site [3].

Although initial results seem to agree with experimental evidence, **at the current point in time it would be premature to draw final conclusions**. The author believes, that the simulation results will significantly impact the course of future technical approaches on LENR.

References

[1] Shoulders, Ken: "Charge Clusters in Action", www.svn.net/krscfs/Charge%20Clusters%20In%20Action.pdf, 1999

[2] Lewis, Edward H.: "Traces of Ball Lightnings in Apparatus", Unconventional Electromagnetics and Plasmas, Vol. 1&2, pp. 89-97, 2008, www.lenr-canr.org/acrobat/LewisEtracesofba.pdf

[3] Lutz Jaitner: "The Physics of Condensed Plasmoids (CP), Ball Lightning and Low-Energy Nuclear Reactions (LENR)", www.condensed-plasmoids.com, 2016