Ultra-dense Hydrogen and Low Energy Nuclear Reactions
Presenter Sveinn Ólafsson Research professor Science Institute University of Iceland

Overview of talk

1. Fusion reactions short overview
2. Palladium Deuterium
3. Nickel - Hydrogen
4. The Ultra-dense hydrogen
5. Theoretical discussion
6. Summary
1. Fusion reactions short overview
Fusion reactions at the core of the Sun

\[ D + D \rightarrow n + ^3\text{He} + 3.3 \text{ MeV} \]
\[ D + D \rightarrow p + ^3\text{T} + 4.0 \text{ MeV} \]

\[ p + p \rightarrow D + e^+ + \nu_e + 0.42\text{MeV} \]
\[ p + p + e^- \rightarrow D + \nu_e + 1.44\text{MeV} \]

\[ p + D \rightarrow ^3\text{He} + \gamma + 5.5 \text{ MeV} \]
\[ p + ^3\text{He} \rightarrow ^4\text{He} + e^+ + \gamma + \nu + 18.8 \text{ MeV} \]

Radioactive!
Molecular muonium fusion, \( \mu \)-catalysed fusion known since 1947

Coulomb barrier is thin, frequency of tunnelling is high

\[
f = \frac{E_{\text{vib}}}{\hbar} \approx 10^{16}/\text{s}.
\]

Reaction is “directional” or “lined up”
Fusion time is less than one nanosecond
\( \mu \) lifetime is too short to reach beak even

Reaction products are the same as in the Sun!

\[
P_g(E) \equiv e^{-\frac{E_g}{E}}^{1/2}
\]

\[
E_g \equiv 2m_ec^2(\pi\alpha Z_aZ_b)^2
\]
2. Palladium-Deuterium

Pons and Fleischmann
How would scientist start a research on the possibility of cold fusion in year 2015?
Combinatorical Research!
Combinatorial Research!

Metalhydride

Deuterium

Driving force
Deuterium in Palladium

Electrochemical cell

University of Missouri

D\textsubscript{2}O and LiOD
No need to perform the experiment, the results are in

Modest Excess heat 1 - 50W for varying time span

Helium is detected, transmutations are detected

Not limited to Pd or Ni

Radioactivity is quenched! tiny amount of Tritium, neutrons and protons are detected

LENR-CANR.ORG

The library includes more than 1,000 original scientific papers reprinted with permission from the authors and publishers. Bibliography of over 3,500 journal papers, news articles and books about LENR.

www.iccf19.com
“Nanocracks in Palladium are the active sites in Pd”

Conducts online PdD experiments with 0.4W excess heat or \(~10^{12}\) fusion events /sec

Progress report #1- #6
Strengths of proofs compared

Higgs discovery bump 2012
200 events/month?
5σ

Storms Helium bump
0.4W \sim 10^{12} \text{ events/sec}
10-40 \sigma?
The scientific conclusion of the Combinatorical Research

Something is accidentally created, that causes “impossible” nuclear reactions

This has been known for 25 years!

With this simple conclusion it is very strange that it has mostly not been possible to perform funded basic research in this field. Only ineffective recreational basic research has been possible.

Basic research has proven over and over to be the lifeline of practical advances in “science”. Without “funded basic research”, “science” regresses and reverts to witchcraft.
3. Nickel - Hydrogen  

Nickel - Deuterium?

Rossi radioactivity free 1.0 MW Nickel-Hydrogen LENR powerplant is in one year engineering trial in Florida, Patent obtained in USA 2015, report in March 2016?

This investor is chasing a new kind of fusion

Fortune.com  SEPTEMBER 27, 2015, 12:00 PM EDT

A prominent North Carolina investor is backing a new kind of fusion that operates at much lower temperatures than thought possible, which would make it easier to commercialize. So far the early results show promise.

Tom Darden  10M dollar investment
Rossi formula Nickel, LiAlH$_4$, Li and Hydrogen isotope

Rossi explanation, Neutrons in Li,D? are transmuted by unknown process over to Nickel at 1400°C

One very recent candidate theory

**Nuclear Spallation and Neutron Capture Induced by Ponderomotive Wave Forcing**

Rickard Lundin and Hans Lidgren

$^1$Swedish Institute of Space Physics, BKiruna, Sweden $^2$Le Mirabeau, 2 ave des Citronniers, MC 98000, Monaco

But Radioactivity in not suppressed in such theory
Neutrons or Ultra dense hydrogen?
Publications  Leif Holmlid 2015 - 2013

Heat generation above break-even from laser-induced fusion in ultra-dense deuterium
Leif Holmlid
AIP Advances, Volume 5, Issue 8, Pages artikel nr 087129 2015

Charged particle energy spectra from laser-induced processes: nuclear fusion in ultra-dense deuterium D(0)
Leif Holmlid and Sveinn Ólafsson
International Journal of Hydrogen Energy, accepted 19 Okt 2015

Muon detection studied by pulse-height energy analysis: Novel converter arrangements
Leif Holmlid, Sveinn Olafsson
Review of Scientific Instruments, Volume 86, Issue 8, Pages artikel nr 083306 2015

Spontaneous ejection of high-energy particles from ultra-dense deuterium D(0)
Leif Holmlid, Sveinn Olafsson
International journal of hydrogen energy, Volume 40, Issue 33, Pages 10559-10567 2015

Meissner Effect in Ultra-Dense Protium p(l=0, s=2) at Room Temperature: Superconductivity in Large Clusters of Spin-Based Matter
Leif Holmlid, S. Fuelling

MeV particles in a decay chain process from laser-induced processes in ultra-dense deuterium D(0)
Leif Holmlid
Leif Holmlid publications continued

Heat generation above break-even from laser-induced fusion in ultra-dense deuterium
Frans Olofson, Leif Holmlid

Intense ionizing radiation from laser-induced processes in ultra-dense deuterium D(-1)
Sveinn Ólafsson and Leif Holmlid
Research Professor
University of Iceland School of Natural Science and engineering
AVS 62 /SRI Ultra-dense Hydrogen and Low Energy Nuclear Reactions

Ultra-Dense Hydrogen H(-1) as the Cause of Instabilities in Laser Compression-Based Nuclear Fusion
Leif Holmlid

TWO-COLLECTOR TIMING OF 3 14 MeV/u PARTICLES FROM LASER-INDUCED PROCESSES IN ULTRA-DE dense DEUTERIUM
Leif Holmlid
International Journal of Modern Physics E, Volume 22, Issue 12, Pages artikel nr 1350089 2013
Journal Article, peer-reviewed

Direct observation of particles with energy >10 MeV/u from laser-induced processes with energy gain in ultra-dense deuterium
Leif Holmlid
Laser and particle beams, Volume 31, Issue 4, Pages 715-722 2013

Excitation levels in ultra-dense hydrogen p(-1) and d(-1) clusters: Structure of spin-based Rydberg Matter
Leif Holmlid

Laser-mass spectrometry study of ultra-dense protium p(-1) with variable time-of-flight energy and flight length
Leif Holmlid
What is Rydberg atom?

and how do they condense?
Giant Interactions in Rydberg Systems

DFG Schwerpunktsprogramm Giant interactions in Rydberg Systems (GiRyd)

- Rydberg Spectroscopy in External Fields
  - Astro- and Plasmaphysics
  - Semiclassics / Quantum Chaos
  - Cavity QED
- Laser Cooling
  - Bose Einstein Condensation
  - Quantum Information Processing

Rydberg Blockade

SPP GiRyd

- Sensors
  - RF to THz
- Ion Traps
- Quantum Simulations
  - Interaction Engineering
- Hybrids between Rydberg Atoms and
  - Optomechanics
  - Fibers
  - SC qubits
- Molecules
  - Few Body Physics
  - Clusters
  - Impurities
- Rydberg Physics in Semiconductors
- Single Photon Devices
  - Polaritons
Rydberg atom generation

Styrene catalyst Fe₂O₃:K or similar

Desorbed H in 1s state

Adsorbed H

Rydberg state
lowest energy state

Desorbed Rydberg H atom in high quantum number state
lifetime in ms

H₂

K dopant atom

Rydberg Matter Clusters: Theory of Interaction and Sorption Properties
Rydberg matter Frozen plasma?

\[ d = 2.9 \ n_B^2 \ a_0, \]

Any cluster structure is possible

Amorphous
Efficient source for the production of ultradense deuterium D(-1) for laser-induced fusion (ICF)

REVIEW OF SCIENTIFIC INSTRUMENTS 2011

Patrik U. Andersson, Benny Lönne, and Leif Holmlid

Atmospheric Science, Department of Chemistry, University of Gothenburg, SE-412 96, Göteborg, Sweden

Styrene catalyst Fe$_2$O$_3$:K
Time of flight analysis

\[ E_{\text{coul}} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r} \]

\[ E_{\text{kin}} = \frac{1}{2} m v^2 \quad v = \frac{r(t)}{\Delta t} \]

\[ r_o \sim \Delta t^2 \]

\[ \Delta t = t_1 - t_o \]
Cluster breakup

<table>
<thead>
<tr>
<th>Total charge</th>
<th>Total cluster mass</th>
<th>Name</th>
<th>$t_1$ (ns)</th>
<th>$t_2$ (ns)</th>
<th>$t_3$ (ns)</th>
<th>Figures</th>
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<td>2</td>
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<td>2254</td>
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<td>460</td>
<td>1841</td>
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<td></td>
<td>8</td>
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<td>475</td>
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<td>1008</td>
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<td>8</td>
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<td>3</td>
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<td>311</td>
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<td>336</td>
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<td>4$\leftrightarrow$4</td>
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<td>3</td>
<td>6</td>
<td>6(3+)</td>
<td>$\approx$412</td>
<td>$\approx$412</td>
<td>$\approx$412</td>
<td>3,4,6,7,8,9,10</td>
</tr>
</tbody>
</table>
Ultra dense Hydrogen

\[ W = \frac{e^2}{4\pi \varepsilon_0 d}, \]

The CE fragmentation processes in the material D(-1) indicate a common KER of 630 eV. This means an interatomic distance of 2.3 ± 0.1 pm,
2.3 ± 0.1 pm!

Laser Intensity dependency

Frequency dependency
Leifs Holmlid length scales

\[ H(l) = \frac{H(1)}{H(0)} \]

\[ d = 2.9a_0l^2 \]

\[ d = 2.9r_qs^2 \]

\[ l=1, \ d=153 \ \text{pm} \quad l=2, \ d=613 \ \text{pm}, \]

\[ s=1, \ d=0.56 \ \text{pm} \quad s=2, \ d=2.23 \ \text{pm} \quad s=3, \ d=5.01 \ \text{pm}, \]

\[ r_q = 0.192 \ \text{pm} \]

\[ a_0 = 52.9 \ \text{pm} \]

\[ 2.3 \pm 0.1 \ \text{pm!} \]
Heat generation above break-even from laser-induced fusion in ultra-dense deuterium
Leif Holmlid AIP Advances, Volume 5, Issue 8, Pages artikel nr 087129 2015

Calorimetry confirms break even fusion

But is this only fusion?

There is more to this
**Laser induced results**

Mesons, electrons, positron, helium, and neutrons observed

Particle Decay

Target contains catalyst that increases and maintains the D(0), p(0) phase
Meson chain and conservation of energy

\[ D_N(0) \rightarrow \cdots \rightarrow K^\pm \rightarrow \pi^\pm \rightarrow \mu^\pm \rightarrow e^\pm \]

\[ N \times 4 \times 938\text{MeV} \rightarrow \cdots \rightarrow 493\text{MeV} \rightarrow 139\text{MeV} \rightarrow 105\text{MeV} \rightarrow 0.511\text{MeV} \]
These results show directly that the signal at long distance is mainly due to a mixture of intermediate particles formed by decay in the beam. The decaying signals have time constants of approximately 12 and 26 ns for ultra-dense deuterium D(0) and 52 ns for ultra-dense protium p(0). These decay time constants agree well with those for decay of light mesons.

These particles with narrow MeV energy distributions are formed by stepwise decay from particles like HN (0). The main result is that a decaying particle flux is formed by the laser-induced processes. The final muons produced may be useful for muon catalyzed fusion.

The difference observed between the signals for D(0) and p(0) is intriguing. The kaon K_L^0 may be formed in this case of p(0) instead of K^± in the case of D(0). This could mean that a down quark replaces an up quark in the laser-induced processes in p(0) relative to D(0).

\[ \text{D_N(0)} \rightarrow \text{K}^\pm \rightarrow \pi^\pm \rightarrow \mu^\pm \rightarrow e^\pm \]

\[ \text{Nx4x938MeV} \rightarrow \text{493MeV} \rightarrow \text{139MeV} \rightarrow \text{105MeV} \rightarrow 0.511\text{MeV} \]
Meson chain and conservation of energy

Only two possibilities

Coherent multibody fusion

Proton/deuteron to Meson spallation

Quantum entanglement needed

\[ D_N(0) \rightarrow \cdots \rightarrow K^\pm \rightarrow \pi^\pm \rightarrow \mu^\pm \rightarrow e^\pm \]
\[ N \times 4 \times 938 \text{MeV} \rightarrow \cdots \rightarrow 493 \text{MeV} \rightarrow 139 \text{MeV} \rightarrow 105 \text{MeV} \rightarrow 0.511 \text{MeV} \]
5. Theoretical discussion

Rydberg matter D(1)

Plausible ultra-dense matter D(0)
Simple Tunnelling fusion rate model for Coulomb potential

Rate = Gamov probability of crossing the barrier \times \text{attempt frequency}

Reaction crosssections are not included
Calculation are shown for $f = 10^{16}/\text{s}$.

$$P_g(E) \equiv e^{-\frac{E_g}{E}^{1/2}}$$

2.3 ± 0.1 pm!
6. Summary

1. Ultra dense hydrogen can be the source of all or part of Cold fusion LENR related phenomena.
2. Laser induced fusion in Ultra dense hydrogen seemingly produces mesons, possibly in a proton or neutron meson spallation process. (Full $4\pi$ calorimetric high energy particle detection exp. needed)
3. If confirmed, such process releases similar or higher energy than fission of Uranium 200MeV.
4. Rossi Ni-H product commercialized 2016?
5. Limited energy system disruption starts 2016 and takes 5-20 years?
6. Funded basic research in cold fusion starting 2016-2017?
7. Full scale energy system disruption possible 2020-2030?
8. Theory possible 2017-2019?
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Fig. 1. Detector part from vacuum components. The PMT part and the PS part are indicated. Without the PS part, a metal blind flange is used to close the tube.

Fig. 9 — Spontaneous signal with detector 3 m from chamber. The three spectra are taken in sequence from top spectrum, changing converter took 60 s.
FIG. 1. Detector part from vacuum components. The PMT part and the PS part are indicated. Without the PS part, a metal blind flange is used to close the tube.

MCA spectra of 500 s duration. When the converter is to be changed, the PMT enclosure is opened and closed in darkness, with the HV on, with no other change in position of the detector. Another MCA was also used, giving the same beta-like distributions. Most experiments were run in darkness, even with black cloth covering the detector parts to avoid any light leakage.

The electron energy scale of the PS is calibrated by measuring the beta emission from a $^{137}$Cs probe (37 kBq, Gammadata, Uppsala, Sweden). Measurements are made in air with and without a 20 µm thick Al foil in front of the scintillator. The shifting of the beta signal with a blue-filter in front of the PMT is verified, proving that the beta particles interact with the PS. A plot of the square root of the number of counts (signal-background) (Kurie-like plot) gives zero signal due to $^{137}$Cs at 765 channels with gain $Q = 1$ in the amplifier Ortec 440 A and gain 200 in the preamplifier. $Q = 512$ keV gives the approximate calibration of 0.67 keV/channel. A similar calibration of only the PMT in Fig. 2 without the PS gives zero intercept signal due to $^{137}$Cs at 170 channels with the same electronics. This gives an approximate calibration of 3.0 keV/channel. A tentative linear scale is used to tag the various features relative to these calibrations.

The time variation of the total signal was measured by a multi-channel scaler (MCS) with 1 s dwell time per channel (EG&G Ortec Turbo-MCS). The pulse signal from the PMT was analyzed after recording by a fast digital oscilloscope (Tektronix TDS 3032, 300 MHz). A GM detector (Rados RDS-80) gives slightly higher signal where the PMT indicates enhanced external signal. The gamma signal was measured with Mirion Technologies PDS-100G without any higher signal detected at the apparatus. In Table I, some ranges of interest for electrons and muons in Fe, Al, and in the scintillator material are collected.

The place of origin of the beta-type signal must also be known. From tests with a $^{137}$Cs beta emitter, it is apparent that beta electrons even with relatively high energy ($Q = 512$ keV) cannot penetrate the thick metal walls used here for the PMT enclosure without large energy loss. Thus, the electrons

### Table I

<table>
<thead>
<tr>
<th>Particle</th>
<th>Energy (MeV)</th>
<th>Range in steel (mm)</th>
<th>Range in Al (mm)</th>
<th>Range in plastic scintillator (µm)</th>
<th>Range in air (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^-$</td>
<td>0.03</td>
<td>9</td>
<td>10</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>$e^-$</td>
<td>0.1</td>
<td>69</td>
<td>150</td>
<td>0.143</td>
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<tr>
<td>$e^-$</td>
<td>0.3</td>
<td>410</td>
<td>700</td>
<td>1.1</td>
<td></td>
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<tr>
<td>$e^-$</td>
<td>1</td>
<td>0.77</td>
<td>2.0 mm</td>
<td>4000</td>
<td>4.4</td>
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<td>$e^-$</td>
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<td>7.6</td>
<td>26 mm</td>
<td>46 µm</td>
<td>1.3</td>
</tr>
<tr>
<td>$e^-$</td>
<td>20</td>
<td>4.3</td>
<td>11.4 mm</td>
<td>24 mm</td>
<td>4.3</td>
</tr>
</tbody>
</table>

FIG. 2. $^{137}$Cs probe at the PMT with no metal flange. The approximate Kurie plot shows the zero signal intercept at 170 channels corresponding to $Q = 512$ keV.
Thank you for listening