Hall Labs
Very Cold Fusion project review
June 8, 2022
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Outline:
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Discussion of Ver. 0.0

Project Timeline
Our project started on May 5, 2022, but it could be viewed as a continuation of our duplication, 33 years ago at Novatek, of the work of Fleischmann and Pons. The Hall brothers never really stopped thinking about cold fusion!
https://www.facebook.com/permalink.php?story_fbid=10159257757756107&id=578136106

Our first public disclosure of the general concept was made to GitHub on May 31, 2022, with the final edits on June 2: https://github.com/hthalljr

My effort to date has focused on understanding the literature and trying to design an experiment to test the concept.

Project scope
To avoid association with the scandal of "cold fusion," some have adopted the term "low energy nuclear reactions" (LENR). Since I'd like to keep the scandal alive, I've dubbed our project "Very Cold Fusion: "Very Cold, " because I think it will work best at cryogenic temperatures. We hope to succeed near 77 K (liquid nitrogen is relatively cheap and abundant), but if that's not cold enough, 40 K is reasonably accessible in a closed-cycle cryostat. Palladium deuteride (PdDx) is known to be superconducting at 10-12 K, with x ranging from 0.7 to 1.0, and a metastable superconducting state has even been induced at about 60 K, with x at about 0.95. I believe that cold fusion is caused by isolated pockets of high temperature superconductivity, as high as the boiling point of water, but bulk superconductivity hasn't yet been seen because the active pockets are always surrounded by normal, resistive material.

My hope is to develop materials and procedures that enable, simultaneously, both fusion and bulk-shorting superconductivity. By bulk-shorting I mean that there is sufficient connectivity between the superconducting regions to "short circuit" the predominant bulk resistivity. (The electrical model is that of variable resistors in parallel: when any single resistance is reduced to zero, the resistance of the circuit is zero.) When excess heat is observed, it appears to come from isolated microscopic regions of unknown composition and structure. The energy of fusion, having nowhere else to go, appears as heat. If, however, superconductivity is indeed involved, it might be possible to achieve a sufficiently high enough concentration of active sites to enable continuous filaments of superconductivity to extend throughout the material. If such a material is fashioned into a resonating microwave cavity, the fusion energy might well be manifest as microwaves, which can be converted to electricity with high efficiency.

Review of the most applicable literature

The Rectantenna:

The rectenna, invented by W. C. Brown in 1963, converts microwaves to electricity. Every RFID tag and proximity smart card is powered by a rectenna. At 2.45 GHz (microwave oven frequency), efficiencies of 91% have been achieved. https://en.wikipedia.org/wiki/Rectenna

Reports of cause and effect between excess heat and superconductivity

(Search terms: "cold fusion," "LENR," "Low energy nuclear reactions," "superconductivity")

Within a year of the March 23, 1989 announcement by Fleischmann and Pons, Mario Rabinowitz of the Electric Power Research Institute (which also sponsored Michael McKubre's excellent experimental work) noticed historical and scientific parallels between high temperature superconductivity and cold fusion and outlined a theory that attempted to explain cause and effect.

"High Temperature Superconductivity and Cold Fusion," M. Rabinovitz, Modern Physics Letters B Vol. 04, No. 04, pp. 233-247 (1990)

https://ui.adsabs.harvard.edu/abs/1990MPLB....4..233R/abstract (Abstract)

Five years later, Rabinovitch and three others reviewed 25 (!) of the theories proposed up to that time and concluded that none of the theories (including Rabinovitch's own) explained the experimental data.

"Critical review of theoretical models for anomalous effects in deuterated metals," V.A. Chechin, V.A.Tsarev, M. Rabinowitz, and Y.E. Kim, Int. J. Theo. Phys. 33, 617-670 (1994)

http://arXiv.org/abs/nucl-th/0303057

More recently, Frederick J Mayer of Ann Arbor, Michigan interpreted the roughly parabolic shape of the plot of resistivity vs. D concentration in PdDx, as measured by McKubre, as the action of two non-interacting electron fluids, one normal and one superconducting. As the concentration of D increases, it creates scattering centers that increase resistivity. The resistance ratio R/R_0 increases to a maximum value of about 2 at x = 0.7 and then drops to about 1.4 at x = 1. Mayer attributes the drop in resistivity at higher x to isolated pockets of superconductivity, which makes sense to me.

However, he then rushes in where angels fear to tread and offers a theory! He invents a new object consisting of a deuteron and two electrons that is about 1/10 the size of the familiar D^- ion and calls it a "tresino." The lowly tresino not only explains cold fusion, but also explains excess heat production in the interior of the earth, and even dark matter!

"Superconductivity and low-energy nuclear reactions," Frederick J Mayer, Results in Physics, 12 (2019) 2075-2077.

https://www.researchgate.net/publication/331188080_Superconductivity_and_Low-Energy_Nuclear_Reactions

Mayer is the only other person I know of who is suggesting a cause-and-effect relationship between superconductivity and cold fusion, but his theory is not testable. I have no theory at all, but if our experiment succeeds in producing microwaves, theorists will be beating down our door.

Interestingly, much of the search for high temperature superconductors focuses on "superhydrides" – materials where hydrogen is squeezed into a solid at such high concentrations that it behaves like elusive holy grail of superconductivity -- metallic hydrogen. There is even a recent claim (March 2022) of "hot superconductivity" in a superhydride. All these experiments involved extreme pressures between the tiny flats of diamond anvils, and no diamond-anvil device is ever going to boil a cup of water.

https://www.insidescience.org/news/heated-debate-rises-over-hints-superconductivity-above-boiling-temperatures

Superconductivity in PdD_x but without fusion (?)

The publication that most informs my experiment avoids any mention of cold fusion: "Superconductivity in palladium hydride and deuteride at 52–61 kelvin," H. M. Syed, T. J. Gould, C. J. Webb and E. MacA. Gray, Queensland Micro- and Nanotechnology Centre, Griffith University, Nathan 4111, Brisbane, Australia, 2017. e.gray@griffith.edu.au
https://arxiv.org/abs/1608.01774

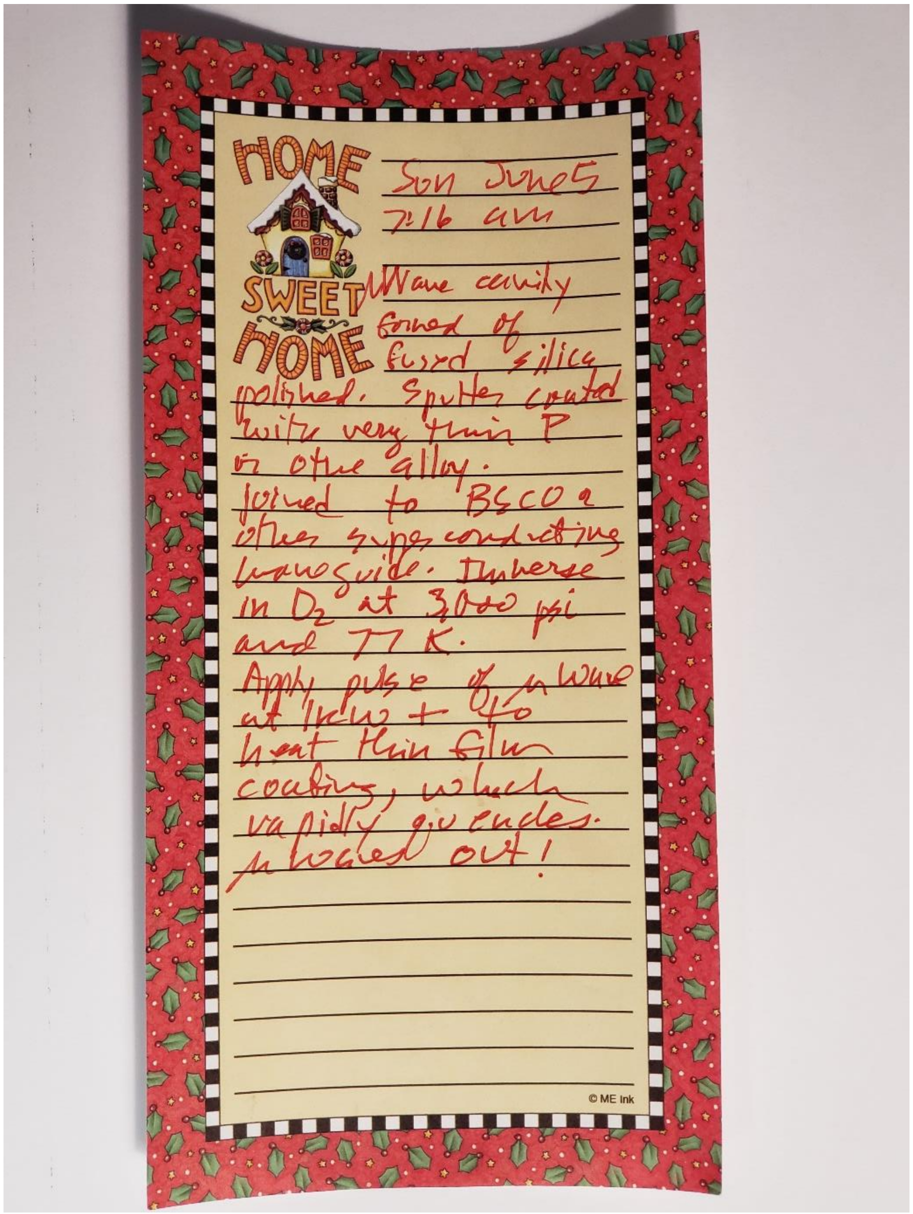
This group built a stainless-steel pressure vessel, connected 4-point resistivity leads to each end of a serpentine Pd wire, annealed it in vacuum at 500 C and then pressurized it to 10 MPa (1450 psi) at 300 C. This positioned the pressure, temperature, and composition outside the two-phase region in the Pd-D phase diagram, so that there only a single high-temperature phase formed. They then quenched the tube in liquid nitrogen, while maintaining constant deuterium pressure, and cooled it on down in a closed-cycle cryostat to 40K. Quench time was of the order of half an hour, and estimated ratio of D to Pd was 0.95.

They observed superconductivity in many, but not in all runs, with a maximum critical temperature (Tc) of about 60K. They explain the hit-and-miss experimental success in terms of percolation theory, where the superconducting centers must typically occupy about 30% of the volume in order to obtain a continuous superconducting network. They obtained a higher success rate with D than with H and suggest that the slower diffusion rate of D enabled a non-equilibrium superconducting state to persist longer and at higher temperatures than with H. Their calculations suggest that as the lattice expands and most of the octahedral sites in the Pd lattice are filled, the smaller tetrahedral sites become thermodynamically favored. They attribute the superconductivity they observed to quenching-in of tetrahedrally-occupied sites.

First experimental design

Early Sunday morning, June 5, 2022, I received an idea for how to create a resonant microwave cavity based on a thin film of Pd or any other material that can support cold fusion. The film can be extremely thin, even down to a few atomic layers. It will exhibit fairly high, easily measurable resistivity in the normal state for contrast with the superconducting measurement. It can be heated rapidly to high temperatures, perhaps of the order of 1000 C, and can be cooled very quickly to cryogenic temperatures. There's a huge pool of variables to play with: Coating material, coating thickness, possible multi-layers temperature, pressure, and quenching rate over a wide range. Somewhere in that forest we hope to find our tree.

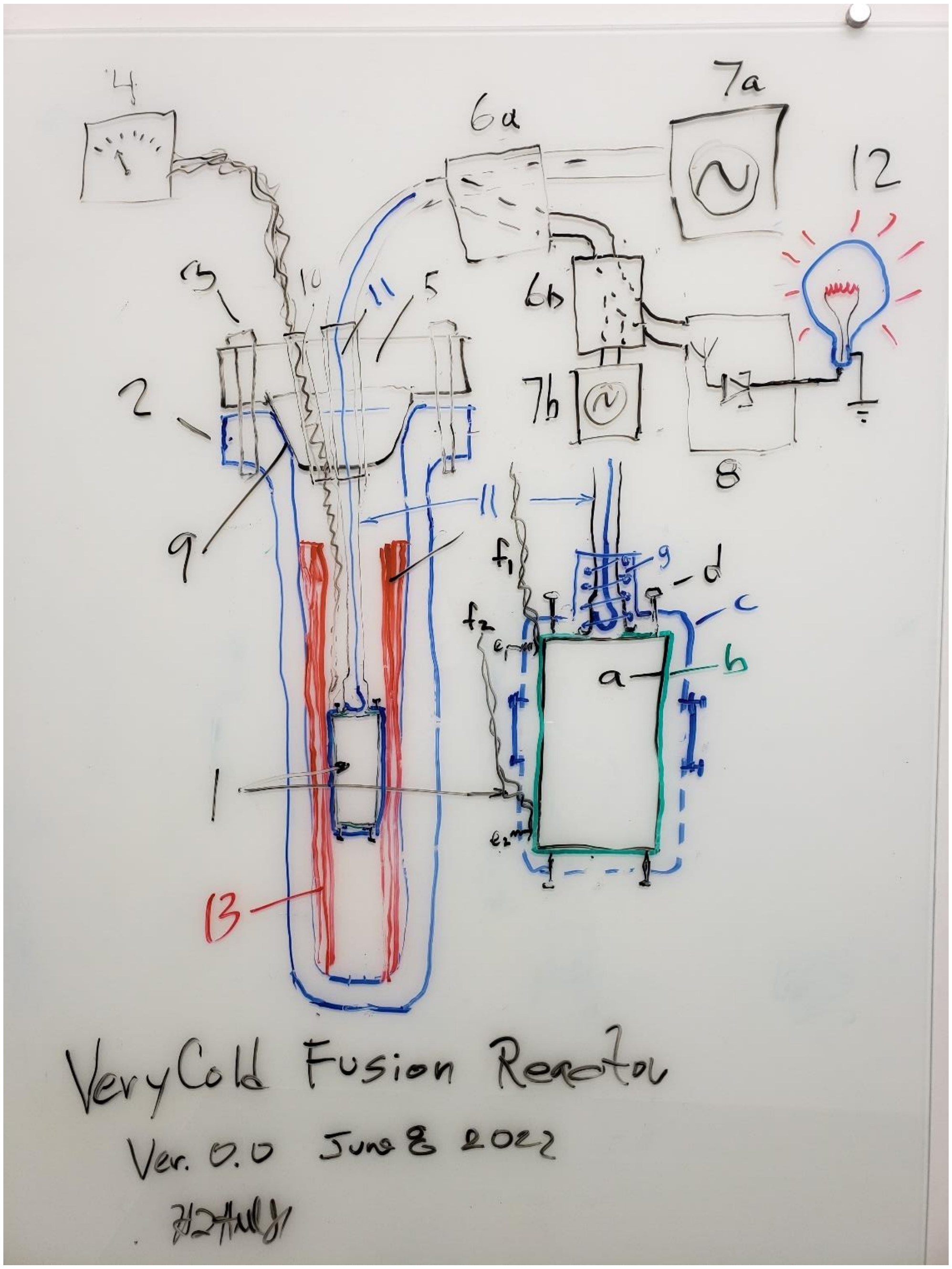
Here's the initial idea, jotted down in in SLML (shopping list markup language) a few hours after it first congealed:



Loose translation:

Sunday June 5
7:16 a.m.
Microwave cavity
formed of
fused silica,
polished. Sputter-coated
with very thin Pd or other
[hydride-forming] alloy.
Joined to BSCCO [Bismuth
strontium calcium copper
oxide] or other
superconducting
waveguide. Immerse
in D2 at 3,000 psi
and 77K.
Apply pulse of microwaves
at 1 kw + to
heat thin film
coating, which
rapidly quenches.
Microwaves out!

Here’s a whiteboard sketch of the concept, as it evolved from June 6 to June 8, 2022



1. Polished cylinder of fused silica, also a. of inset.
2. High pressure cylinder.
3. Bolt circle.
4. 4-point resistivity meter.
6a, 6b. Microwave switch.
7a. High power microwave generator: 1 kw?
7b. Microwave signal analyzer.
8. Rectenna.
9. Pressure sealing surface.
10. Sealing plug for 4-point resistivity wires.
11. Waveguide or coax.
12. Power (we hope) from rectenna.
13. Thermal mass of copper.

Inset

a. Polished cylinder of fused silica
b. Thin Pd coating on cylinder to create microwave cavity.
c. Perforated split cage positions the cavity and enables electrical contacts to the thin coating (b). via spring loading.
d. cavity mounting screws.
e-1, e-2. Upper & lower spring-loaded contacts to 4-point resistivity wires.
f-1, f-2. Upper & lower current-voltage pairs for 4-point resistivity measurement.
g. Spring that holds coax or waveguide against the thin coating b.
Not shown: line for pressurization and vacuum, liquid N2 dewar or cryostat.

Discussion of Version 0.0

With no theory to predict the operating frequency, it will be governed by the dimensions of whatever cavity is reasonable to build. If we want to pick up some of our equipment at a thrift store, the 2.45 GHz microwave oven frequency would be convenient, but it would require a rather large pressure vessel: a design for a cylindrical cavity that is tunable from 2 to 4 GHz is 13 cm diameter x 19.6 cm length, with a 3.5 cm diameter tuning rod. Note the use of sapphire as a dielectric, which would be an elegant (and expensive) substitute for fused silica.
"2-4 GHz Slotted Cavity Prototype Simulations," Mark Jones, Pacific Northwest National Laboratory, Nov. 18, 2020.
https://indico.fnal.gov/event/46436/contributions/202529/attachments/137537/171681/MJones_-_2-4_GHz_Simulations_Collaboration_Presentation_Nov_2020.pdf

Although we'll initially work at liquid nitrogen temperatures (77 K), we might need to go as low as 40 K, and the choice of a closed-cycle refrigerator will then control its dimensions.

I failed to include the pressure/vacuum line in the sketch. The reactor will need to be evacuated to a high vacuum and should also sustain a deuterium pressure of about 5,000 psi. The alloy should not be susceptible to hydrogen embrittlement.

The polished silica cylinder will initially be coated with Pd, by any vacuum or vapor-phase process. To facilitate coupling to microwaves, it should be at least one skin-depth thick. The skin depth of Pd at room temperature, in micrometers, is 5.23 at 1 GHz; 1.65 at 10 GHz; 0.52 at 100 GHz. One micrometer = 39.37 microinch.
https://www.rfcafe.com/references/electrical/cond-high-freq.htm

A layer of platinum, even as thin as one atomic layer, is known to enhance hydrogen absorption in palladium nano cubes, so a Pt coating should be in the experimental matrix.
"Accelerating Hydrogen Absorption and Desorption Rates in Palladium Nanocubes with an Ultrathin Surface Modification," Lucy Metzroth, E. Miller, A. Norman, S. Yazdi, G. M. Carroll, Materials Science, Chemistry Nano letters, 2021.
https://www.semanticscholar.org/paper/Engineering-Palladium-Surfaces-to-Enhance-the-of-Hamm-Dmitriyeva/847aa3b2e2d2e3332eaba858a753e4765b49c886#paper-header

Fused silica has a very low coefficient of thermal expansion. (I used to scare my colleagues at Novatek by taking a fused quartz tube, glowing orange at 800 C, out of the furnace and immediately cooling it off under running water.) Metals have much higher expansion coefficients. Upon cooling, the coating will be in tension under the restraint of the silica cylinder. Deuterium absorption causes Pd to swell, causing the coating to want to pull away from the cylinder. If the coating remains intact, separation from the cylinder should be no problem. Perhaps the cylinder should even be coated with graphite or hexagonal boron nitride before applying the metal.

Four-point probe measurements might not be needed: it is possible via microwave vector analysis to measure the resistivity of the cavity.

The microwave design is obviously in its infancy and will influence all other features. I’m not yet sure whether to bring the signal into the pressure chamber via a coaxial cable of a waveguide, nor am I sure how to couple the signal into the cavity. Conceptually, I’ve left the top center of the cavity uncoated and coupled its emissions into the wave guide with a short loop antenna.

[end]