Archive of ideas for possible future experiments, September 27, 2022

Yesterday after Sunday School my brother-in-law, Ron Spears, shared with me his impression that if cold fusion was real, and if the Lord was ready to give it to men, He would reveal it as such a simple process that an ordinary person could accomplish it. That resonated with me, and I told him that this was indeed my hope. However, as I thought more about it this morning, I recognized that none of the ideas I've developed in last five months are truly simple!

Accordingly, I have decided to first attempt a simple, inexpensive experiment, using a very high pressure of deuterium to induce cold fusion in a either a thin layer of Pd or in Pd nanodots lining the inside diameter of a silica capillary. This won't fulfill our project's long-term goal of converting fusion energy directly to electricity, but it has a good chance of producing abundant heat at temperatures approaching 600 °C, where the heat can be converted to electricity in the same manner as coal and nuclear thermal plants.

The concepts archived here have been developed since my last update of July 25, 2022.

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A Search for Positive Feedback from RF-Excitation of Fusion in Palladium Deuteride

We will attempt to extract the energy of cold fusion directly as electromagnetic energy at a radio or microwave frequency that can be efficiently rectified (somewhere between 1 MHz and 20 GHz[1].)

A Search for Positive Feedback from RF-Excitation of Fusion in Palladium Deuteride

Friday September 23, 2022 best concept to date: Deposit Pd quantum dots in the nanotube array in a thin "alumite" disk, which serves both as the nuclear-active site and as a dielectric for re-entrant cylindrical resonator. The disk is placed between beryllium copper pistons that are sealed with Bridman seals in a quartz tube. The seals might be indium or Teflon. The Id of the quartz ID must be very smooth, clean, and scratch free, designed with a safety factor of about 10 at a pressure of about 100,000 psi (710 MPa). It's not a very large volume, so the cavity resonator will provide protection against possible failure. Follow the procedure of T. Masuda et al[2] to prepare a 50 micrometer-thick disk of alpha-alumina (sapphire) having through-holes 69-58 µm in diameter, using 40 V with oxalic acid and (Table S1) and the heating curve to 1200 °C (a) of Fig. S1[3]. and deposit Pd quantum dots by the procedure of J. J. Gong et al[4], then heat in

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[1] https://en.wikipedia.org/wiki/Rectenna, accessed 23 Sep 2022.

[2] T. Masude et al, "Fabrication and Characterization of Single Phase α-Alumina Membranes with Tunable Pore Diameters, Materials 2015, 8, 1350-1368, https://www.mdpi.com/1996-1944/8/3/1350

[3] Masude et al, *Ibid*, Supplementary Materials, https://www.mdpi.com/1996-1944/8/3/1350/s1

[4] J. J. Gong et al, "Palladium Quantum Dots Sensitized TiO_2 Nanotube Arrays for Highly Efficient Photoelectrocatalytic Hydrogen Generation," Clean Technology 2011, www.ct-si.org, ISBN 978-1-4398-8189-7, https://briefs.techconnect.org/wp-content/volumes/Cleantech2011/pdf/351.pdf

vacuum to 500 C to remove all hydrogen before placing the disk in the reactor. The disk is held in place by gravity on the lid of re-entrant cavity, with the movable piston above. Immerse assembly in liquid nitrogen before introducing deuterium. Start with low pressure introduced from a calibrated small volume to get quantitative D/Pd ratio in quantum dots, whose mass is known from the deposition process. Low pressure also provides easier excitation of the RF/microwave plasma. Then turn plasma off, incrementally increase pressure, monitor additional uptake, then strike plasma on, and repeat process until maximum pressure is achieved. As a control, do this first with the same crystallized alumina disk before depositing the quantum dots.

Concept summary

The nuclear-active material will comprise quantum dots of Palladium deposited in nanometer-diameter tubes extending through and normal to the two surfaces of a thin dielectric disk made of Al_2O_3 or TiO_2. The disk will be positioned between the capacitor plates of a re-entrant cylindrical radio-frequency cavity. The Pd dots will be so highly loaded with deuterium that they

Background

During the third of a century that has elapsed since the initial discovery by Fleischmann and Pons[5], thousands of experiments in scores of laboratories have produced heat, measured with high confidence, that far exceeds anything that can be produced by any chemical process[6,7]. However, none of these have yet produced commercially useful energy. The excess heat is of low grade, rarely exceeding 100 Celsius, which is not generally thought capable of producing useful mechanical work or electricity. (The Carnot theorem limits the efficiency of any heat engine to the ratio of the temperature difference between the source and the exhaust and the temperature of the source[8]. Given a heat source at 100 C (373K) and a heat sink at room temperature of 25 C (298K), the maximum efficiency of a perfect heat engine will be (373-298)/373, or about 20%).

Ironically the expected overall power balance for the "DEMO" D-T plasma fusion reactor, the planned successor to the $21 billion ITER project, is only expected to be about 17%[9]! So cold

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[5] Martin Fleischmann & Stanley Pons, "Electrochemically induced nuclear fusion of deuterium," J. Electroanal. Chem, 1989, 261: 301 and errata in Vol. 263. https://www.lenr-canr.org/acrobat/Fleischmanelectroche.pdf

[6] Jed Rothwell, "Lessons from Cold Fusion archives and from history," in ICCF Conference 2013, University of Missouri. https://www.lenr-canr.org/acrobat/RothwellJlessonsfro.pdf

[7] Jed Rothwell, Answer to a question on Quora, 2017 https://www.quora.com/Is-there-any-experiment-to-date-that-can-convincingly-demonstrate-that-LENR-occurs/answer/Jed-Rothwell

[8] https://en.wikipedia.org/wiki/Carnot%27s_theorem_(thermodynamics)

[9] Derk Stork, "DEMO and the Route to Fusion Power," 3rd Karlsruhe Int. School on Fusion Technology, Sep. 2009, page 90. https://fire.pppl.gov/eu_demo_Stork_FZK%20.pdf

fusion already has better thermal efficiency than the dominant hot fusion project, still far in the future, that will cost many billions of dollars!

Just the same, why not dispense with the Carnot cycle and try for 100% efficiency?

In the reigning billiard ball paradigm, where conservation of energy and momentum conservation between two particles is determined with simple vectors in a center of mass frame of reference, D-D fusion has three possible branches. The main two branches, which are about equally probable, are neutron (2.452 MeV) + helium-3 (0.817 MeV), or proton (3.025 MeV) + tritium (1.008 MeV). The third branch requires is Helium-4 (7.6 keV) + gamma ray (23.7 MeV)[10], with a probability of about one part per million: it requires an exact head-on collision. (Imagine two sharp-shooters facing each other and simultaneously firing their guns with such precision that the bullets collide and come to a dead stop halfway between them.

It is this billiard-ball paradigm that led to the "dead graduate student" dilemma[11]: the neutrons thought necessary to account for the excess heat in the Pons-Fleischmann experiment should have killed the experimenters. I was at the Fleischmann-Pons press conference on March 23, 1989. At its conclusion I was given a tour of their laboratory by their graduate student, Marvin Hawkins, who is still very much alive[12].

It is now well established that helium-4 is indeed the major product in D-D cold fusion. Why would fusion in a lattice enable a million-to-one reversal in the branching ratio of billiard ball fusion? Most theorists believe it has something to do with both deuterium and helium-4 being bosons. An unlimited number of bosons can occupy a single quantum state[13], and their collective action results in many counter-intuitive properties. It is surmised that some form of collective action enables two deuterons to fuse into one Helium-4 in such a fashion that the energy of fusion is dissipated to the He-4 ground state by a multitude of tiny transitions that couple the energy into the lattice as heat.

One of the most dramatic examples of a bose condensation is when Helium-4 condenses to a superfluid: a state of zero viscosity. As a student I worked with liquid helium in a double cryostat that had a thin viewing slit. At atmospheric pressure it boils at 4.22 K. By pumping on it, I forced it to boil hard, extracting heat from the liquid and from the sample I was studying. It boiled vigorously until it cooled to 2.17 K, where it instantly transitioned to the superfluid state, with the gas-liquid interface becoming as smooth as glass.

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[10] V. A. Chechin, V. A. Tsarev, M. Rabinowitz, Y. E. Kim, "Critical Review of Theoretical Models for Anomalous Effects (Cold Fusion) in Deuterated Metals," Int. J. Theo. Phys. 33, 617-679 (March 1994), eqs. 4,5, & 6 https://arxiv.org/ftp/nucl-th/papers/0303/0303057.pdf

[11] H. Fox & R. Bass, "Cold versus hot fusion branching ratios," Proc. 16th Int. Symposium on Fusion Engineering, Champaign, IL, Aug. 2002 (abstract). https://ieeexplore.ieee.org/document/534535

[12] https://www.linkedin.com/in/marvin-hawkins-72149b68/

[13] https://en.wikipedia.org/wiki/Boson

Theory, at least respectable theory, always follows experiment, but so far experiment hasn't inspired a quantitative theory for cold fusion, nor for its helium-4 product. Theorists are in general agreement, however, that some collective state of deuterium atoms must be involved. Helium-4 is itself a boson.

The reason the temperature of a cold fusion reactor is limited is because the solubility of deuterium in palladium decreases rapidly with increasing temperature, such that the heat of fusion ends up driving deuterium out of the lattice, resulting in negative feedback. So why not look for D-D fusion in palladium at say, "Very Cold" temperatures?

Conditions for excess heat.
Any cold fusion experiment should attempt to meet the conditions that are generally understood to be necessary to produce excess heat. In electrochemically driven cold fusion, four conditions are believed necessary for producing excess heat[14]:

Thermodynamic pre-conditioning is required.
i. A high loading or chemical potential of D in the Pd Lattice is needed. The bulk average ratio of D to Pd should exceed 0.95, but it might be considerably higher than this in isolated nuclear-active sites[15].

Instead of obtaining this condition by extended electrolysis in D_2O on a bulk palladium cathode, we will obtain it by providing atomic deuterium in a high-pressure cold plasma to nanometer-sized particles of deuterium at liquid nitrogen temperatures. (A "cold" plasma is one that is out of equilibrium, the temperature of the electrons being much higher than the temperature of the gas.) Atomic deuterium has a very high chemical potential, the surface energy of nanometer-sized particles adds to that chemical potential, and thermodynamics drives a higher D/Pd ratio with decreasing temperature The most recent work I could find on the solubility of H and D in Pd, by Sharpe et al, [16] who extended previous data from 273 K (0 C) down to 130 K (-143 C).

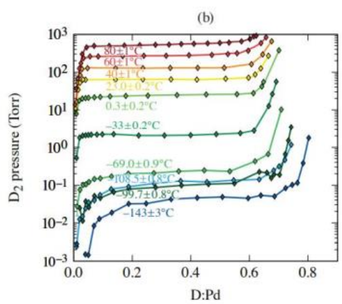
The solubility of D in Pd at 273 K is 0.6 D/Pd; at 130 K it is about 0.75 D/Pd. (Per Gibb's phase rule[17], the pressure in the two-phase region where alpha PdD and beta PdD coexist must be constant). At 350 K the 2-phase region extends from about .08 D/Pd to about 0.6 D/Pd at a constant pressure of about 6×10^3 torr (8 bar, 800 kPa); at 130 K it extends from about .15 D/Pd

[14] M. McKubre, F. Tanzella, P. Hagelstein, K. Mullican, M. Trivithick, "The Need for Conditioning in Cold Fusion Reactions," 10th ICCF Conference, 2003. https://www.lenr-canr.org/acrobat/McKubreMCHtheneedfor.pdf

[15] M. Sharpe et al, "Measurement for Palladium Hydride and Palladium Deuteride Isotherms between 130 K and 393 K," LLE Review, V. 159, p. 177 (May 2019). https://www.lle.rochester.edu/media/publications/lle_review/documents/v159/159_16_Sharpe.pdf

[16] M. Sharpe et al, "Measurement for Palladium Hydride and Palladium Deuteride Isotherms between 130 K and 393 K," LLE Review, V. 159, p. 177 (May 2019). https://www.lle.rochester.edu/media/publications/lle_review/documents/v159/159_16_Sharpe.pdf

[17] https://en.wikipedia.org/wiki/Phase_rule



to about .75 D/Pd at a pressure of about $3x10^{-2}$ torr ($4x10^{-5}$ bar or 4 Pa).
(For full resolution of the thumbnail, see Sharpe et al, Fig. 1d, p. 178).

ii. An initiation time at twenty to fifty times larger than the D diffusion time constant is required. Although full loading of 1 mm diameter wires can be obtained in 8-12 hours, initiation time is of the order of 160-190 hours; for 3 mm diameter wires those values are, respectively, 24-36 hours and 300-500 hours.

Our experiment will use nanometer-sized particles of deuterium, which should render moot both limitations due to diffusion considerations and time for development of the nuclear-active environment.

Suitable triggering is needed:
iii. A minimum or threshold electrochemical surface current or current density is required that is not correlated to the bulk D loading. This should be greater than 250-500 mA per square centimeter, which is some 20 times the current density needed to obtain high loading. Triggering can be initiated both by increasing and decreasing the current density.

We anticipate providing current densities much higher than this and will ramp the current up and down at MHz frequencies.

iv. Not only should the current though the lattice be varied: it is also necessary to obtain a cyclic flux of deuterium through the lattice. In electrochemically driven cold fusion, this is accomplished not only by a flux of deuterium normal to the axis, but also by a flux of deuterium along the axis. Three fluxes are thought to play a role: (1) Motion of Pd atoms: lattice vibrations; (2) motion of D atoms, especially against a strong gradient in D concentration, and (3) flow of electrons through the lattice, both perpendicular to and parallel to the axis of the cathode.

We anticipate that the intense, high frequency electric field in our experiment, coupled with the nanometer size of the Pd particles, will strong drive all three of these fluxes.

Our concept:

Instead of partitioning the energy of fusion into lattice vibrations and excess heat, we hope to partition it into oscillations of an electric field, which produces atomic deuterium in a low-pressure cold plasma. (A cold plasma[18] is one in which the gas molecules are so far apart that they can't achieve equilibrium with the highly-energetic electrons).

We will investigate two modes of operation:

1. Operation in a high MHz to GHz electric field with a cold deuterium plasma.

2. Operation in a high MHz to GHz electric field without the plasma.

[18] https://en.wikipedia.org/wiki/Nonthermal_plasma

Our experiment will be conducted between the capacitor plates of a reentrant cylindrical resonant cavity that is immersed in liquid nitrogen. Low-power RF excitation at 327 MHz will be fed into the cavity to excite a low power but super-hot diffuse deuterium plasma between the plates. An optical fiber will couple light form the discharge to a UV-visible spectrometer and will be monitored for the (In hot, diffuse portions of the interstellar medium, the pressure is lower than can be achieved by the best vacuum system on earth and although the temperature is about which is a One (or perhaps both) of the plates will be faced with a thin metamaterial comprising nanometer-sized palladium particles and a porous low-dielectric constant matrix. The oscillating neutral D atoms in the plasma will load and drive a super-cold, condensed deuterium plasma in the palladium lattice. I believe, as do many, that the primary nuclear product in condensed-matter fusion is helium-4 [19, 20]. Spectroscopic observation of the diffuse plasma should even enable detection of the Helium-4 ash if it builds up in the cavity. Deuterium pressure in the cavity will be maintained just above the minimum on the Paschen [21] curve necessary to enable ionization, on the order of 500 volts and 1 torr (133 Pascal).

One frequency of particular interest will be the hyperfine spin-spin transition in atomic deuterium, the frequency of which has been measured with great precision: 327.3843525222 MHz [22]. The Hyperphysics web site gives a good explanation of the hydrogen hyperfine transition [23]; deuterium is analogous, but with a smaller energy split. The great precision in the measurement arises from the long lifetime of the excited state: for hydrogen, it is about 10 million years [24].

Mitchell R. Swartz [25] reported maser activity at the 327 MHz D line in "LANR- Lattice Assisted Nuclear Reactions." He observed the activity in three different experiments conducted in a one-wavelength (.916 meter) Fabry-Perot cavity. Although the electric field in his aluminum-foil

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[19] Peter L. Hagelstein, Michael C. H. McKubre, David J. Nagel, Talbot A. Chubb, & Randall J. Hekman, "New Physical Effects in Metal Deuterides," 11th International Conference on Condensed Matter Nuclear Science, 2004, Marseille, France (A review prepared for the U.S. Department of Energy. See section 3, "Helium and Excess Heat," pp. 7-9) https://www.lenr-canr.org/acrobat/Hagelsteinnewphysica.pdf

[20] Melvin H Miles, "Correlation of Excess Enthalpy and Helium-4 Production, a Review," 10th International Conference on Cold Fusion, 2003.
https://www.academia.edu/80462066/Correlation_of_excess_enthalpy_and_helium-4_production_A_review

[21] https://en.wikipedia.org/wiki/Paschen%27s_law

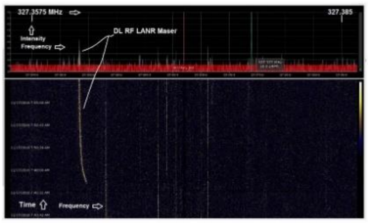
[22] D. J. Wineland & N. F. Ramsey, "Atomic Deuterium Maser," Phys. Rev. A 5, 821, Feb. 1972 https://journals.aps.org/pra/abstract/10.1103/PhysRevA.5.821

[23] Hyperphysics: The Hydrogen 21-cm line. http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/h21.html

[24] J G Subils & J T Roca, "Hyperfine structure in hydrogen: the 21 cm line," Univ. Barcelona, June 2015 http://diposit.ub.edu/dspace/bitstream/2445/67394/1/TFG-Gomez-Subils-Javier.pdf.pdf

[25] Mitchell R. Swartz, "Active LANR Systems Emit a 327.37 MHz Maser Line," Journal of Condensed Matter Nuclear Science, Proceedings of the ICCF 22 Conference, September 8–13, 2019, Assisi, Italy, pp 81-110. https://www.lenr-canr.org/acrobat/BiberianJPjcondensedzf.pdf#page=87

maser cavity was extremely weak, Schwarz was able to readily detect it with an amateur radio "duck" antenna coupled to an inexpensive USB dongle and a software-defined radio (SDR [26]).



A preamplifier sends the in-phase and quadrature (I/Q) signals [27] from a TV tuner chip to the SDR, which executes most of the radio functions. The SDR displays a broadband radio frequency spectrum accompanied by a "waterfall" display showing its temporal history. (I have used a similar setup, minus the cavity, in my own amateur radio work.)

(For full resolution of the thumbnail, see Schwarz, Fig. 1, p. 82)

Swartz did not assert that his fusion reaction was driven by the observed maser activity but rather saw it as a diagnostic signal proving that "the deuteron, in the excited pre-4He state, is a free radical emitting from an FCC vacancy." Significantly, the D line was observed only while the experiments were producing excess heat, the magnitude of which could only be explained as a nuclear effect. One was an electrolytic cell evocative of the original experiment of Fleischman and Pons; the other two were dry reactors involving low voltage DC electrical stimulation of Pd-Ni alloy nanoparticles dispersed in a ZrO_2 matrix in deuterium gas. Interestingly, the electrolytic experiment involved ordinary water and a nickel cathode, leading Swartz to suggest that nuclear activity in hydrogen-based experiments is, in fact, not from hydrogen, but from the minor deuterium component in natural hydrogen (typically about 154 parts-per-million [28]).

I intend to use the 327 MHz D-line not only to detect fusion, but also to drive it. A strong RF field will be developed between the plates of a re-entrant cylindrical resonator cavity that is oscillating in klystron mode. This will excite a low-density, super-hot deuterium plasma that will drive atomic deuterium into nanometer-sized particles of palladium which are embedded in a thin, porous, low-loss dielectric. The Rf electric field will synchronously drive the super-cold bosonic deuterium plasma within the lattice, creating a population inversion that will catalyze D-D fusion. Maser activity will couple the fusion energy back into the RF field, where it can be extracted from the cavity and rectified to provide electricity.

Re-entrant resonator cavities have long been used to provide high RF fields, beginning with the 1937 invention of the klystron microwave vacuum tube by Russel and Sigurd Varian at Stanford University [29]. Any resonant cavity that provides spatially separated electric and magnetic fields is said to be operating in klystron mode. We will be using a cylindrical re-entrant cavity, which inserts a conductive post along the axis of the cylinder to form a capacitor between the end of the post and the lid of the cavity. The post itself is the inductor. Since the energy is stored in the capacitor and inductor, rather than the electromagnetic fields, a klystron-mode cavity can be much smaller than the wavelength that excites it, and it can be modeled as a lumped LCR (inductance, capacitance, resistance) circuit. Adjusting the gap can tune the cavity over a wide range of frequencies; the frequency is so sensitive to the gap that reentrant cavities are used

[26] RTL-SDR.COM: Software defined radio news and projects: https://www.rtl-sdr.com/about-rtl-sdr/

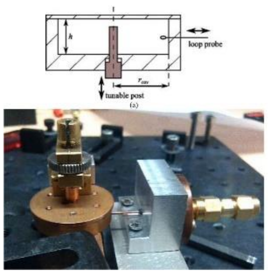
[27] Peter Barret Bryan, "Mind your I's and Q's: The Basics of I/Q data," https://towardsdatascience.com/mind-your-is-and-q-s-the-basics-of-i-q-data-d1f2b0dd81f4

[28] https://en.wikipedia.org/wiki/Deuterium

[29] https://en.wikipedia.org/wiki/Klystron

for precision metrology, including detection of tiny oscillations in a 1-ton spherical gravitational wave detector [30].

J.-M. Le Floch et al [31] give formulas for the cylindrical reentrant cavity, using both lumped LCR equations and finite element analysis. The two methods agree well for small gaps (klystron mode). They built a copper cavity with a movable post that was tunable from 2 GHz to 22 GHz. Multiplying their dimensions by a factor of 10 would give a cavity tunable from 200 MHz to 2.2 GHz, suitable for our experiment. I am developing a spreadsheet for our design based on their formulas: “Reentrant cavity.xls)”.



(For full resolution of this thumbnail see Le Floch at all, Fig. 7, page 7.)

Our experiment will be conducted in a low pressure of deuterium at liquid nitrogen temperature. (77K, -196 C). RF power at 327 MHz is coupled into and out of the cavity by small inductive loops near the inner wall of the cylinder. Power will be slowly increased until a plasma ignites between the plates of the capacitor. To keep everything cold, power and will be maintained at the lowest level needed to maintain the plasma. The 327 MHz D line is a protected frequency for radio astronomy, and the experiment will have to be conducted in well-grounded Faraday cage. (MIT’s Haystack deuterium observatory in Westford, Massachusetts had to take extensive measures to mitigate interference: the chief culprit was consumer electronics in their vicinity [32].) Because the absorption of D into Pd (at least up to D/PD = 0.7) is exothermic, the concentration of D in Pd is enhanced with decreasing temperature. (The diffusion rate of D in bulk Pd slows to a crawl), but it should still be adequate for nanometer-sized particles.) The high surface energy of nanometer-sized also increases the thermodynamic equilibrium concentration of deuterium.

The state of the plasma will be monitored through an optical fiber leading to a UV-visible spectrometer. The Balmer series for hydrogen and deuterium are nearly identical. The plasma appears pink-violet in color, with wavelengths, in nm: 656 (red), 486 (aqua), 434 (blue), 410 (violet), and 397 (ultraviolet) 33 If fusion occurs, sufficient Helium-4 will eventually build up to enable its spectrum to be observed. Helium is so named because it was first discovered in the

[30] O. D. Aguiar, “The Brazilian Spherical Detector: Progress & Plans,” 5th Edoardo Amaldi Conference on Gravitational Waves, Tirennia (Pisa) Italy, July 6-11, 2003. https://dcc.ligo.org/public/0034/G030372/000/G030372-00.pdf

[31] J-M. Le-Floch et al, “Rigorous analysis of highly tunable cylindrical Transverse Magnetic mode re-entrant cavities,” Review of Scientific Instruments 84, 125114 (2013). https://arxiv.org/ftp/arxiv/papers/1308/1308.2755.pdf

[32] A. E. E. Rogers et al, “Radio frequency interference shielding and mitigation techniques for a sensitive search for the 327 MHz line of deuterium,” Radio Science 40, 2005 https://www.researchgate.net/publication/259306613

[33] https://en.wikipedia.org/wiki/Balmer_series

spectrum of the sun. A helium plasma appears violet-blue in color: its strongest lines are 706 (red), 668 (red), 501 (green), 447 (blue), and 388 (violet)[34].

Although there is yet to emerge a quantitatively rigorous model for lattice-assisted nuclear reactions, there is a general understanding that some cooperative action of deuterium atoms must be involved, which is probably dispersed in the palladium as a tiny minority of "nuclear-active sites". Atomic deuterium is a bosun, which allows many particles to occupy a single quantum state. Superfluidity of helium-4 and superconductivity in many materials are driven by condensation of bosuns, and some speculate that the nuclear-active site also involves superconductivity. (Discuss Australian work).

Many experiments have established that a high ratio of D to Pd is required, more than 1/1. A high abundance of vacancies in the lattice is also thought to be helpful, as is maintaining a flux of deuterium through the nuclear-active site. A dielectric meta-material for the plates of the capacitor will be

The capacitor plates will consist of a metamaterial comprising nanowires of palladium filling a hexagonal array of nanometer-sized channels in aluminum oxide that are formed by acid anodization. This process has already been extensively used to create metallic nanowires, including palladium nanowires, but to my knowledge, the oxide is always dissolved away to obtain separate nanowires. I propose to leave the wires in place to form a metamaterial that exploits the dielectric properties of the Al2O3 while orienting the Pd nanowires parallel to the electric field.

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Needed:

Spreadsheet for calculating frequency and Q of re-entrant cavity from dimensions.

Calculate setup for 323.37 MHz deuterium hyperfine transition.

_Mitchell R. Swartz, "Active LANR Systems Emit a 327.37 MHz Maser Line," Journal of Condensed Matter Nuclear Science, Proceedings of the ICCF 22 Conference, September 8–13, 2019, Assisi, Italy, pp 81-110

Summarize Swartz observations both with NANOR (Zr2O3 with nano-sized Pd-alloy, direct current) and PHUSOR (electrolytic in ordinary water, but activity coming from the small trace of deuterium). Hyperfine transition observed in full wave Fabry-Perot 36-inch long maser cavity ONLY when excess heat is being produced.

Re-entrant cavity is modeled as lumped circuit: parallel LCR: L is component between post and walls, C is between re-entrant post and lid, so its dimensions are dictated by the values those components and not by the wavelength, which is .91758 meters (36.125"). Nuclear active component is a metamaterial on each face of the gap: dielectric comprising nanowires of Pd

[34] https://www.vernier.com/vernier-ideas/a-quantitative-investigation-of-the-helium-spectrum/

electroplated into the hexagonal array of holes formed by anodizing chemically polished aluminum in acidic bath

First create a quick mock-up to test a re-entrant cavity, possibly using a cookie tin. Once those parameters are established, build a prototype cavity in silver-plated copper. Tune it at room temperature to 327.3 MHz, then at LN2 temperature, then explore pressure-power space for lowest power D2 plasma. (Copper is difficult to machine, but necessary for high thermal conductivity. Investigate more machinable Cu alloy, provided it still has high thermal conductivity.) Silver plate to about three times skin depth.

Then machine back the faces of the copper capacitor posts to make room for metamaterial capacitor.

Develop metamaterial dielectric for capacitor.

Filtered structure of Pd nanospheres. Multiple possibilities, in order of priority.

0. Pd quantum dot decoration of sapphire disk with nanometer through-holes (above)

1. Explode Pd wire in D2 atmosphere: goal is D-saturated nanoparticles with super-abundant vacancies.
The suspended nanoparticles might begin fusing and possibly burn themselves out? If so, do it at 77K.
Collect them by pumping through nanometer-thick porous filter (does this exist?) Control by darkness of layer. Stack multiple layers, press together.

2. Self-assembly of flash-melted layers, alternating with porous ceramic
Select a ceramic that is not wetted by molten Pd
Sputter or hot-wire coat 20 nm layer of Pd
Flash layer with laser so that it melts and re-assembles into array of nanospheres.
Repeat for multiple layers.

3. Nanowires in hexagonal array of holes in anodized aluminum.
Chemical polishing of aluminum
Anodizing process & convert to sapphire
Electroplating of Pd into nano holes
- Difficulty: wires are about 100 nm in diameter. A better size might be 15-20 nm.
Possible improvement: striped wires: deposit alternate layers of 20 nm Pd, 20 nm Cu

Yet another possibility: Build Bridgeman Anvil in re-entrant cavity: PdD at 5 GPa (50 kbar).
Alumina anvils, coated with silver to thickness of about 3 skin depths.
Prepare any of the above metamaterials, attach to one of the anvils with silver paste.
Insulating polymer ring gasket
Pressurize cavity to about 1 kbar D2
Close anvils, trapping D2; metamaterial occupies about 10% of space. Squeeze to 5 GPa.
Hard to run at LN2 temperature, but this would help with D2 density. Once compressed, low

temperature might not be needed.

The primary problem to be addressed is getting the Pd nanostructures into a nuclear-active state.

Needed:

High D-Pd ratio: equilibrium ratio increases with decreasing temperature, but diffusion slows. Nano dimensions should help. Cite McKubre, Storms.

High D-flux should be driven by high electric field along nanowires. Cite electromigration work. High temperatures help with most experiments producing heat, in contradiction of our “very cold fusion”idea.

Work on easiest solutions first: Lowest-possible power RF activation of D2 plasma at 77 K.
Use optical fiber to obtain plasma spectrum. If we get fusion and produce enough power, eventually spectrum of He-4 will appear and increase in intensity.
First pump heat entire reactor to 500 C in high vacuum, cool under vacuum, to LN2, admit about 1 torr of D2, watch for pressure drop.
Differential coefficient of thermal expansion between Al2O3 and Pd will leave tiny gap between nanowires and surrounding insulator, allowing for penetration of atomic D along entire length.

Monitor temperature with thermocouple behind each metamaterial to control RF power: keep as cold as possible. Periodically check Q of cavity.
Check for production of RF power: it might be necessary to continue to stimulate the system with low power RF input.

Variables to pursue to enhance performance, or if first approach fails.
Tune anodizing process for narrow wires, longer wires.

Nickel instead of Pd?

Other H-absorbing alloys electroplated or evaporated into nanotubes.
Intensify plasma to provide local heating to 300C while still immersed in LN2, then quench.
Use of collapsible spring behind metamaterial can allow heating with some thermal isolation: Collapse spring to quench.

Create plasma at T>300C and quench while continuing plasma.

If quenching from 300 C to 77 K doesn’t achieve nuclear-active state, follow the lead of the Australian group, which quenched from 300 C to 50 K under high deuterium pressure. This would necessitate a cryocooler and working with high pressure gases. Gas volume could be reduced by filling most of the resonant cavity with a low-loss dielectric, which would require new dimensions.

A circular permanent magnet, as is used in magnetron sputtering, could be placed outside the top of the cavity to check for the Zeeman effect and to possibly enhance the nuclear activity, but it may also suppress superconductivity.

(Friday, 16 Sep 2022: about 5 pm. electrode: Pd nanowires in hexagonal channels, formed by anodizing aluminum. Al is sputter-coated on copper sputter-coated on alumina Bridgman anvils functioning as the capacitive portion in a copper re-entrant cavity. Follow Sayed-et al recipe for superconducting PdD, but at first cool only to 77 K (liquid nitrogen) instead of 40 K, which requires a cryocooler. Anneal 500 C 8 hours in vacuum, cool to 300 C, load with D2 to 10 MPa 100 bars, 1450 psi), confined at high pressure between anvils, fed with high pressure stainless-steel capillary. Quench in liquid nitrogen as fast as possible. System is first characterized (VNA scan) at same conditions with aluminized channels, then later when channels are filled with Pd nanowires.

Also, what happens if Pd is deposited in the pores of leached polycrystalline diamond and then electrolyzed? PdD is 10% expanded with respect to D. What happens when that expansion is restricted? Will superabundant vacancies result? Remember that PCD is leached because it is destroyed at about 600 C by the differential thermal expansion of cobalt and diamond. But perhaps a stronger nano-porous material exists: Al2O3? TiO2?

Sat 17 Sep 2022, 9:51 am. Thoughts in shower. Go for simplest form of Pd first: either thin sputter-coat or thin co-deposited layer. Obtain heating to 300 and rapid quench to 77 K by using a heat switch that still conducts electricity – they exist commercially: see beryllium copper alloy #25 wave spring washers (https://www.smalley.com/materials/special) or beryllium copper Belleville washers https://jtdstamping.com/precision-washers-belleville/beryllium-copper , or make one from rod, sheet, foil, or silver-plated spring wire at EBay or Amazon. There's another complex type that fills the whole circle that I have seen. Make the active capacitor plate (or both, if necessary) of small mass, with a thermocouple welded to the back side coming through the thermal switch. Heat to 300 C with microwave power while the cavity is immersed in liquid nitrogen. It may be necessary to have a thin layer of high-loss dielectric behind the Pd to act as a heater. The plate also is also threaded onto a thing screw welded to a piano wire that extends through the heat switch to an actuator outside the cavity that is externally driven, inside a nickel bellows assembly, to rapidly pull the hot capacitor plate against the heat switch.

In this write-up, summarize all the possible ways the active layer on the capacitor plate can be provided, keeping first to the rapid quench method

Sunday 18 Sep 2022, 6:00 a.m. (idea came to me after awakening at 4:45 a.m.)

Instead of Bridgman anvils, use a piston and cylinder sealing in D2 at 3,000 psi (twice the pressure of Syed et al.) Pistons are made of beryllium copper, cylinder is made of transparent Al2O3 (GE Lucalox?). (Need to calculate strength of cylinder in tension). Fixed short piston is sealed in a groove in the lid of the cylindrical cavity with indium. Faces of both pistons are sealed to ID of cylinder with Bridgman seals (https://en.wikipedia.org/wiki/Bridgman_seal) made of indium. Pressure is brought in through a stainless steel capillary in fixed piston. The moving piston is cylindrical, of length sufficient to sweep the reentrant cavity through the desired frequency range. Below the cylindrical portion it is conical for massive support. Use, as the active element, an anodized TiO_2 hexagonal array of nano-sized tubes decorated with Pd quantum dots. (I've seen the paper, but evidently didn't save it. It might be this, but I can't find a PDF online and have written the authors for a reprint):

"High-Efficiency Photoelectrocatalytic Hydrogen Generation Enabled by Palladium Quantum Dots-Sensitized TiO2 Nanotube Arrays," Meidan Ye, Jiaojiao Gong, Yuekun Lai, Changjian Lin, and Zhiqun Lin, J. Am. Chem. Soc. 2012, 134, 38, 15720–15723
https://pubs.acs.org/doi/full/10.1021/ja307449z

The high dielectric constant of TiO2 should facilitate its heating in the HF field. Bond a very thin, porous alumina layer to the face of each piston. It could even be the free-standing anodized aluminum arrays offered by ACS Nanomaterials: https://www.acsmaterial.com/single-pass-aao-5-pack.html. The idea is that the spacer, having a low dielectric constant, won't heat up in the RF field – just the Pd@TiO2 disk. It might be desirable to convert the TiO2 to rutile by heating in argon to about 1200 C, either before or after decorating with the Pd quantum dots. While immersed in LN with full pressure of D2, tune the cavity to the 327.37 MHz D line (Mitchell R. Swartz, ICCF22, p. 81), and slowly increase microwave power while monitoring the visible spectrum through the cylinder walls and an optical fiber. When it's up to about 600 C, it should be seen in the far red. Then turn off the power. The high pressure D2, in close proximity to the beryllium-coper pistons that are at 77 should cause a very rapid quench. See what happens: further loading of quantum dots and excitation of fusion might be needed at low RF power, insufficient to cause significant heating. Problem: if cold fusion occurs and couples to the RF field, that will heat the TiO2 dielectric. If so, use anodized aluminum array instead, and find some other way to heat the quantum dots to above the PdD triple point of 300 C.
- finished at 7:20 a.m.

Monday September 19, 2022, 1:00 p.m.
Instead of heating the Pd with microwave excitation, heat it with direct DC current. Use the free-standing anodized aluminum array from ACS Nanomaterials and fill the pores with electroplated Pd. This might best be done directly on the fixed cathode, in which case it should be made detachable from the cavity. The electrolytic filling would provide firm attachment of the Pd wire array and Al2O3 spacers to the cathode. It might be desirable to convert the amorphous Al2O3 to sapphire by high temperature annealing. Overfill the pores slightly, so that the Pd nanowires extend beyond the Al2O3. Electrically insulate the base of the movable cathode and equip it with a movable copper shunt that can later connect it electrically to the inside of the cavity. Close the movable cathode onto the Pd nanowires, all under high D2 pressure at 77K, and pulse-heat them. Monitor the temperature through an optical fiber placed so that it views several Pd nanowires through the sapphire medium. Slowly increase the heating pulse until the nanowires is heated to above 300 C – perhaps even 500 C. It might also be desirable, before attaching the Pd nanowire array to the cathode, to preload the nanowires to Pd/D approaching 1. Note that this will place the nanowires in compression and could break up the Al2O3 matrix. If this happens, form the Pd wires by co-deposition of Pd and D, a process which has been observed to immediately initiate excess heat and would avoid stressing the Al2O3 matrix.

The Al2O3 pressure cylinder might need to be strengthened with a surrounding belt of high-tensile strength material, as with my father's "belt" apparatus. This might be accomplished by winding with Kevlar fibers under high tension, preserving a window for the optical fiber with a removable plug. Thereby the experiment would pay homage to the two founders of modern high pressure research: Percy W. Bridgman and H Tracy Hall.

Tues Sep 20, 2022, about noon
To deposit and charge the nanowires by co-deposition, create a small cell with the sapphire nano form held against the detachable beryllium copper plate with aluminum oxide felt, soaking it with an amount of solution sufficient to provide about 125% of the needed palladium. Press against that with a Pt-coated anode, all in a sealed quartz pressure vessel whose ID fits the OD and Bridgman Teflon gasket of the detachable plate. It's possible that sufficient heat will be developed to raise the temperature above boiling point: so do this in a well-insulated calorimiter and see how hot it can get. The critical point of water is 374 C and 22.06 MPa (3212 Pa), and thermal power plants operate at about 540 C and 17 MPa (2400 psi, 160 atm). https://en.wikipedia.org/wiki/Thermal_power_station#Steam_turbine

Fused silica capillaries give an opportunity for safe pressure charging of Pd to 100,000 psi!

Fused silica tubes are made for High Pressure Liquid Chromatography. Thermo Scientific PEEKsil ® capillaries have a silica core coated with PEEK and come with standard HPLC outside diameters of 1/16" (1.59 mm), 1/32" (.794 mm) and .360 mm with inside diameters ranging from 25 µm to 530 µm and pressure ratings (water, straight to 30,000 psi (2 kbar, 20 kPa). A thin Pd wire could be sealed in such a tube at high D2 pressure: perhaps we would see fusion above the 2-phase region at 300 C. Also, the work of Syed et. al. could be replicated, but at higher pressures and with faster quenching: from 300 C into liquid nitrogen. In another experiment, Pd quantum dots could be deposited on the ID.

DPolymicro Technologies division of Molex has an excellent book on their products, with much detail about silica capillaries, handling, cutting, and uses.
https://www.molex.com/mx_upload/superfamily/polymicro/theBOOK.pdf

They coat theirs with polyimide and can go to 350 C and even 400 C, but for some reason, they're only rated to -65C. (I've written to them asking why). The Book," doesn't give pressure capabilities, except to warn that the tiniest scratch on the ID or the OD can yield to premature failure. In the 2006 version of the book, formulas for stress (it's greatest on the ID) are given, with a recommended yield stress of 852.6 ksi (5.88E9 Pa). Examples are cited for routine use to 28 ksi, and an example for "TSP010375 capillary (i.d. = 10 µm & o.d. = 323 µm) **pressurized to ~103 kpsi by Patel et al. offered a safety factor of ~8**."
https://www.molex.com/mx_upload/superfamily/polymicro/pdfs/polyimide_coated_capillary_tubing_internal_pressure_capabilities.pdf

Polymicro/Moex also has .360 mm OD nano capillaries with IDs from 200 nm +- 200, 600 nm +-

200, and 1000 nm +- 500. https://www.content.molex.com/dxdam/literature/987651-3889.pdf?