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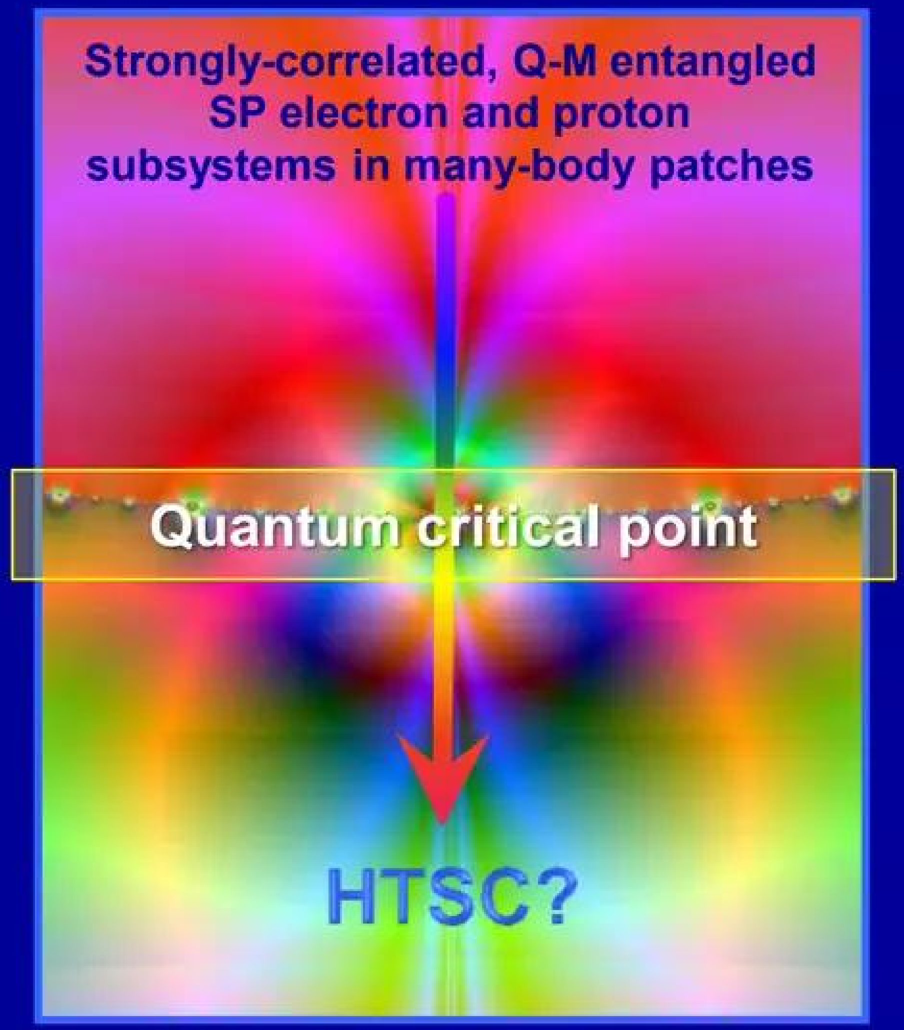
Commercializing a next-generation source of safe CO_2-free energy

Low Energy Neutron Reactions (LENRs)

Speculation: evanescent exotic superconductivity

Is there a form of HTSC in heavy-electron patches?

Tiny hint provided on pp. 2 in Sept. 10, 2005 arXiv:0509269 preprint, "...added heavy electrons produce an anomalously high surface conductivity at the LENR threshold"; i.e., perhaps μ-scale patches temporarily behave like HTSC islands?



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President and CEO

August 23, 2012

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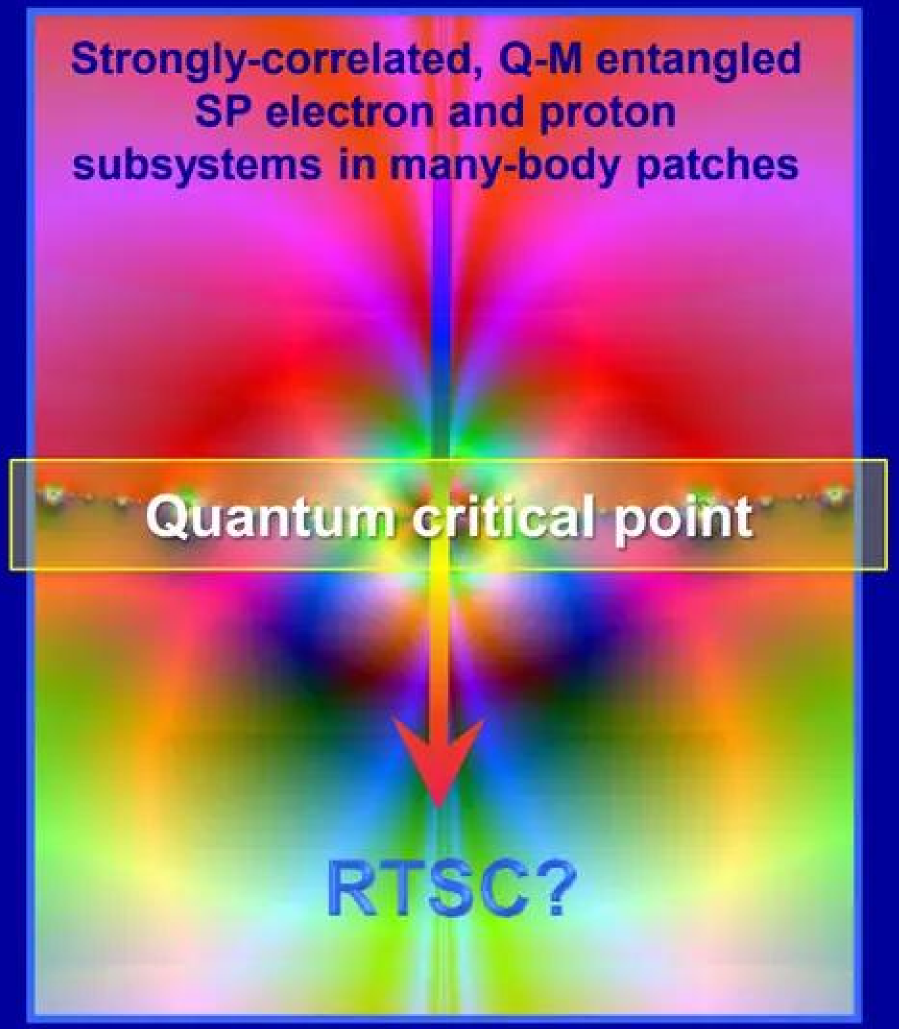
1-312-861-0115

"I have learned to use the word 'impossible' with the greatest caution."

Wernher von Braun

Updated September 21, 2013



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Physics of LENRs is now understood and published

Eight technical papers on Widom-Larsen theory (2005-2010)

"**Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces**" *Eur. Phys. J. C* **46**, pp. 107 (2006) Widom and Larsen – initially placed on arXiv in May 2005 at http://arxiv.org/PS_cache/cond-mat/pdf/0505/0505026v1.pdf; a copy of the final *EPJC* article can be found at: http://www.newenergytimes.com/v2/library/2006/2006Widom-UltraLowMomentumNeutronCatalyzed.pdf
"**Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces**" http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf (Sept 2005) Widom and Larsen
"**Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells**" http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf (Feb 2006) Widom and Larsen
"**Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces**" http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf (v2. Sep 2007) Widom and Larsen
"**Energetic electrons and nuclear transmutations in exploding wires**" http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf (Sept 2007) Widom, Srivastava, and Larsen
"**Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary**" http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf (Feb 2008) Widom, Srivastava, and Larsen
"**High energy particles in the solar corona**" http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf (April 2008) Widom, Srivastava, and Larsen
"**A primer for electro-weak induced low energy nuclear reactions**" Srivastava, Widom, and Larsen *Pramana – Journal of Physics* **75** pp. 617 (2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

pp. 2

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Contents

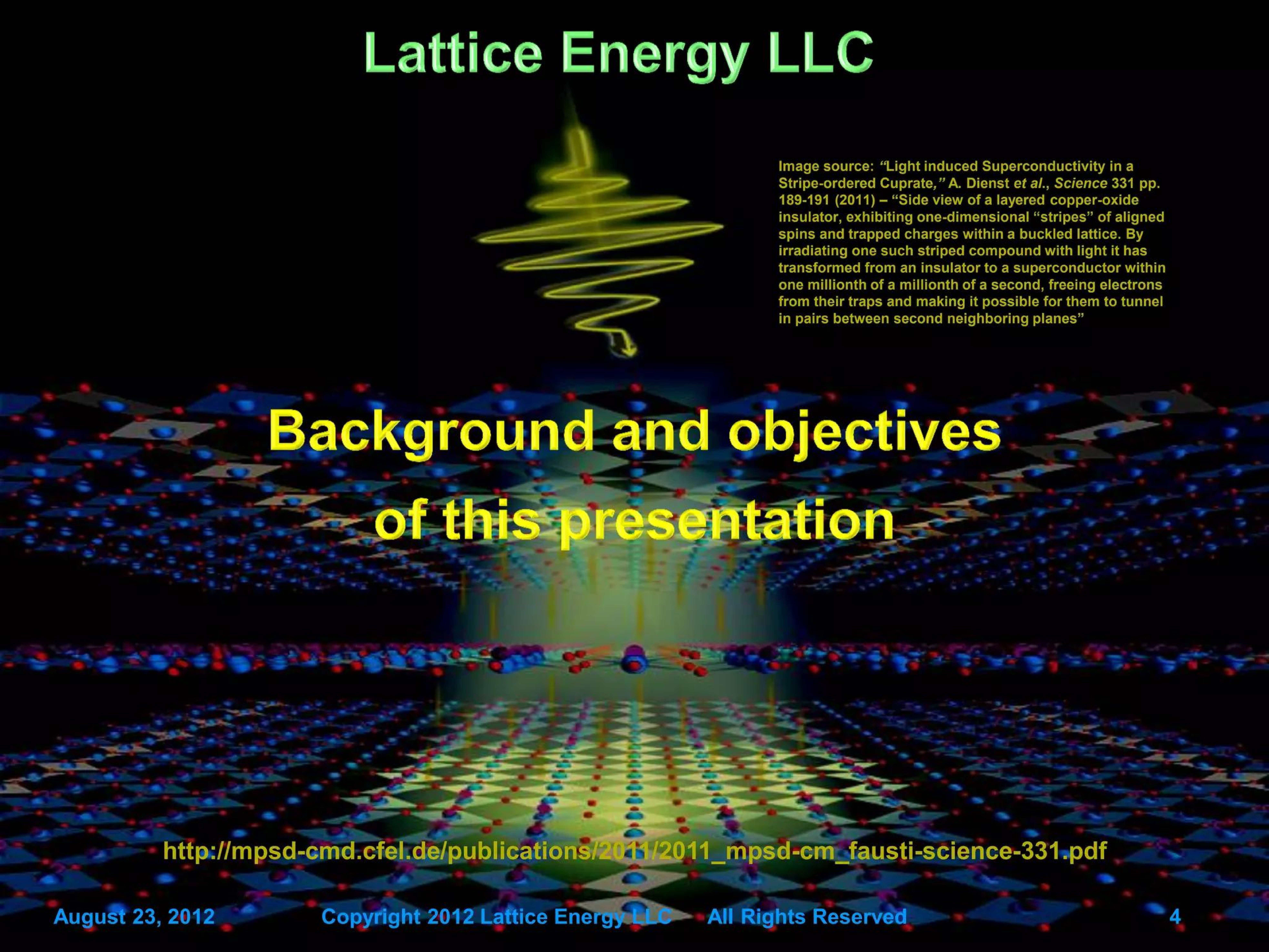
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Image source: *"Light induced Superconductivity in a Stripe-ordered Cuprate,"* A. Dienst *et al.*, *Science* 331 pp. 189-191 (2011) – "Side view of a layered copper-oxide insulator, exhibiting one-dimensional "stripes" of aligned spins and trapped charges within a buckled lattice. By irradiating one such striped compound with light it has transformed from an insulator to a superconductor within one millionth of a millionth of a second, freeing electrons from their traps and making it possible for them to tunnel in pairs between second neighboring planes"
Background and objectives
of this presentation
http://mpsd-cmd.cfel.de/publications/2011/2011_mpsd-cm_fausti-science-331.pdf

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Background and objectives of this presentation

Theoretical insights spurred our interest about HTSCs in LENRs

Conceptual genesis in 2005:

- ✓ **In May - Sept. 2005, while further elaborating the Widom-Larsen theory of LENRs to explain a characteristic suppression of high-energy gamma emissions that has been routinely observed in LENR experimentation for over 20 years, Allan Widom and I noticed intriguing theoretical possibilities that anomalously high surface electrical conductivity might occur in the vicinity of many-body 'patches of entangled, collectively oscillating protons (or deuterons, tritons) at local E-field strength values close to thresholds needed for electroweak neutron production. Not wishing to unnecessarily expand an otherwise relatively concise paper http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf by injecting tangentially related issues, we just remarked on pp. 2 that, "...added heavy electrons produce an anomalously high surface conductivity at the LENR threshold."**

Upon encountering this intriguing theoretical possibility in 2005, author remembered that in 2000:

- ✓ **In early 2000, just prior to funding Lattice, this author first became aware of a series of Italian electrolytic LENR experiments using thin-Pd-wire (50-*μm* dia. --- discussed later herein) cathodes that dated back to mid-1990s in which large fluctuations in electrical resistance measured in wires had been observed in apparent conjunction with calorimetrically measured production of excess heat from very same Hydrogen-loaded Pd ultrathin wires**
- ✓ **Giovanna Selvaggi had just conducted new series of just such Pd thin-wire experiments at the University of Illinois (Urbana-Champaign campus - UIUC). Miley *et al.* reported her interesting results at ICONE, April 2000: showed an especially striking correlation of extreme resistance fluctuations with the onset of excess heat production. At that time, I provided a senior member of the technical staff at Sandia National Laboratories with copies of Ms. Selvaggi's data; the Sandia scientist was a recognized expert on electrical breakdown phenomena related to nuclear weapons and had also done his Ph.D. thesis on a topic involving superconductivity, interestingly in the UIUC Physics Dept.**
- ✓ **After studying Selvaggi's data, Sandia expert said: "... it looks weird," and that, "Such large, very rapid fluctuations in resistance values may indicate either (a) breakdown of Pd conductor [ultrathin wire] because of electromigration effects, or (b) possibly some type of evanescent, fluctuating 'superconductive-like' behavior inside the material."**

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Background and objectives of this presentation

Earlier experimental work suggests HTSC possibility maybe real

In 2005, Lattice discovered that there had been earlier patenting activity in this area:

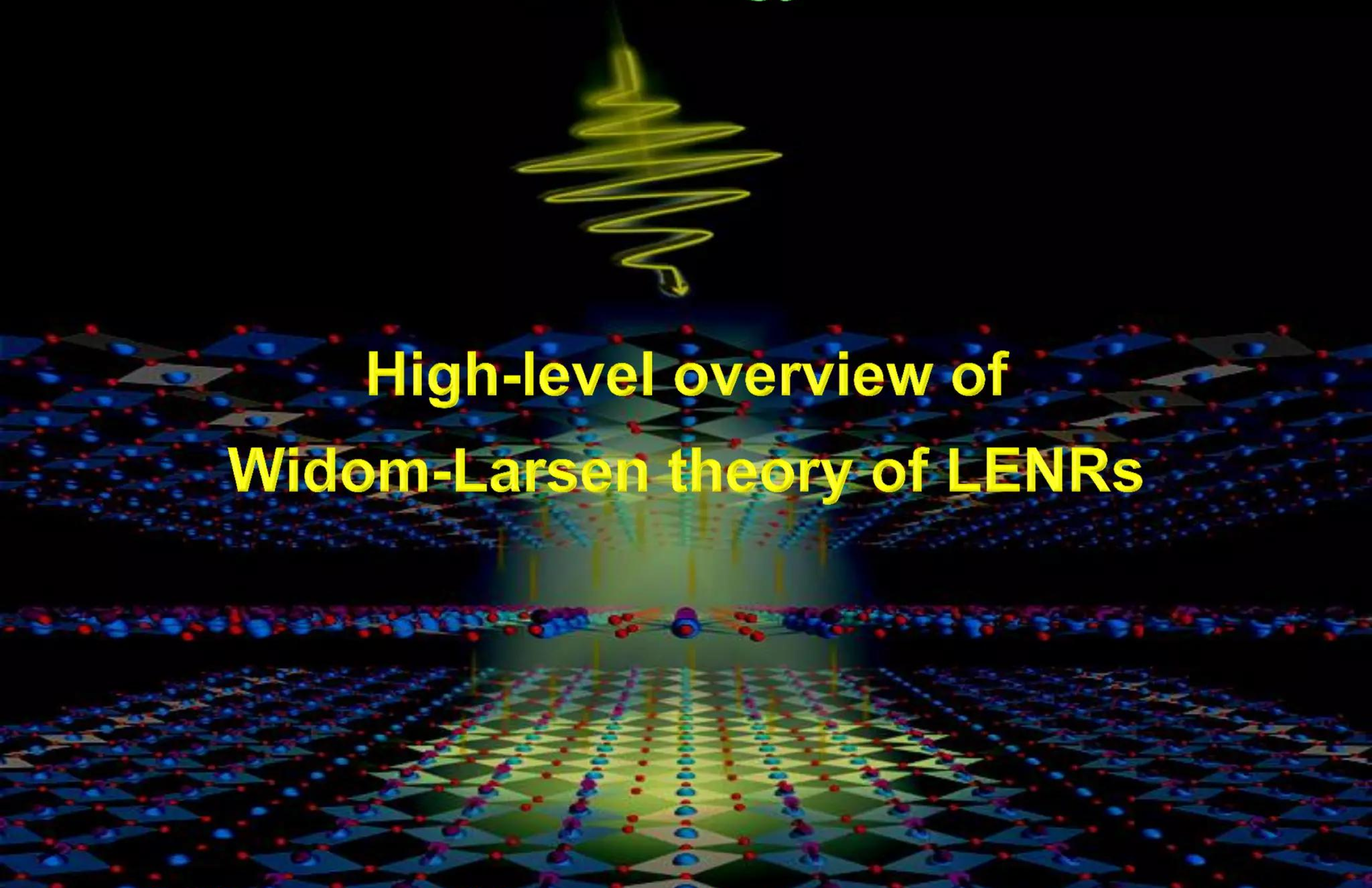
- ✓ In 2001, PCT patent application, "HIGH T_c PALLADIUM HYDRIDE SUPERCONDUCTOR" was filed by Paolo Tripodi (former coauthor and collaborator of Francesco Celani in Italy in 1990s); it was eventually granted and issued in USA as US #7,033,568 B2 in 2006 http://ip.com/patfam/xx/22693758 . Quoting: "... invention discloses a Palladium hydride superconducting material, $Pd^{y}H_x$ where $^{y}H_x$ is $^{1}H_x$, $^{2}H_x$, or $^{3}H_x$ and x is the stoichiometric loading ratio of $^{y}H_x$ to Pd in the material. The superconducting material has critical temperatures $T_c \geqq 11$ K for stoichiometric loading ratios $x \geqq 1$. The critical temperature linearly depends upon a power of the stoichiometric loading ratio. Samples have been produced having critical temperatures of 51.6 K, 80 K, 82 K, 90 K, 100 K, and 272.5 K." Were these old T_c measurements correct?

  Note

  Lattice comment: such high loading ratios are difficult to achieve in practice and can be *very* fleeting and unstable; thus it may be nearly impossible to build practical HTSC devices using the methods taught in Tripodi's 2006 patent

Objectives and limitations of this presentation:

- ✓ Herein, we will discuss the possibility that evanescent high-temperature superconductivity (HTSC) may well be occurring in LENR systems; note that this document contains informed speculation which is intended to (and very definitely should) raise many more questions in most readers' minds than it answers --- indeed, that is one objective
- ✓ Let it be clear that the author is decidedly not a subject matter expert in superconductivity and is not yet conversant with the mathematical details of a subset of string theory now being applied in condensed matter with some promise
- ✓ That said, as a co-developer of the Widom-Larsen theory of LENRs, the author believes that extant published experimental data cited herein suggests that evanescent HTSC well-above room temperature may well be occurring in LENR systems; if that speculative conjecture proved to be correct, it might have important technological implications
- ✓ Not surprisingly, another objective is to arouse the intellectual curiosity of subject matter experts in the possibility of utilizing ideas discussed herein to spur further investigation of some fascinating science questions; these new ideas are not intended to be definitive but rather an exploratory foray into a little-known *terra incognita;* a roughly sketched explorers map created to help provide impetus for additional theoretical and experimental work by other researchers



High-level overview of Widom-Larsen theory of LENRs

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Conditions needed to trigger LENRs in condensed matter

Widom-Larsen theory elucidates key initiation parameters

- ✓ Substantial quantities of Hydrogen isotopes must be brought into intimate contact with fully-loaded metallic hydride-forming metals; e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc.; please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At full loading of H, many-body, collectively oscillating island-like patches of protons (p^+), deuterons (d^+), or tritons (t^+) will form spontaneously at random locations scattered across such surfaces
- ✓ Or, delocalized collectively oscillating π electrons that comprise the outer covering surfaces of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, entangled quantum systems that, within context of W-L theory, are functionally equivalent analogues to loaded metallic hydrides
- ✓ Born-Oppenheimer approximation breaks down in tiny surface patches of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at these locations; creates nuclear-strength local electric fields > 2 x 10^{11} V/m; effective masses of electrons in that field are then increased to a multiple of an electron at rest ($e \rightarrow e^*$) - determined by required ~simultaneous energy input(s)
- ✓ System **must** be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SP or π electron surface films. Examples of such external energy sources include (they may be used in combination): electric currents (i.e., electron 'beams'); E-M photons (e.g., emitted from lasers, IR-resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across surfaces; currents of other ions crossing the SP electron surface in either direction (ion beams); etc. Such sources can provide additional input energy required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ weak interactions
- ✓ **N.B.:** please note again that surface plasmons are collective, many-body electronic phenomena closely associated with interfaces. For example, they can exist at gas/metal interfaces or metal/oxide interfaces. Thus, surface plasmon oscillations will almost certainly also be present at contact points between purely metallic surfaces and adsorbed target nanoparticles composed of metallic oxides, e.g., PdO, NiO, or TiO_2, etc., or vice-versa

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There's no free lunch and no free energy in W-L theory

Input energy is required to produce neutrons and thus trigger LENRs

- ✓ **Input energy is required to create non-equilibrium conditions** that enable nuclear-strength local E-fields which produce populations of heavy-mass e^{-*} electrons that react with many-body surface patches of p^+, d^+, or t^+ to produce neutrons via $e^{-*} + p^+ \rightarrow 1\ n$ or $e^{-*} + d^+ \rightarrow 2\ n$, etc. (cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes **(these can be combined):**
  - **Electrical currents** (i.e., an electron beam of one sort or another)
  - **Ion currents** across the interface on which SP electrons reside (i.e., an ion beam that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used to input energy is by imposing a pressure gradient (Iwamura *et al.* 2002)
  - **Incoherent E-M photon fluxes** (under right conditions, SP electrons can also be directly energized with coherent laser beams emitting photons at resonant wavelengths); Letts & Cravens (2002) discovered laser LENR effect; includes resonant electromagnetic cavities
  - **Organized magnetic fields with cylindrical geometries,** mainly at very high current densities; includes organized non-ideal, so-called dusty plasmas and scales-up to stellar flux tubes
- ✓ **Key feature of complex, multi-step LENR transmutation networks** is that large numbers of viable network pathways can release more net nuclear binding energy from combination of neutron captures (w. direct conversion of gammas into IR) and decays than amount of input energy needed to produce total # of neutrons required for network pathway(s) to operate

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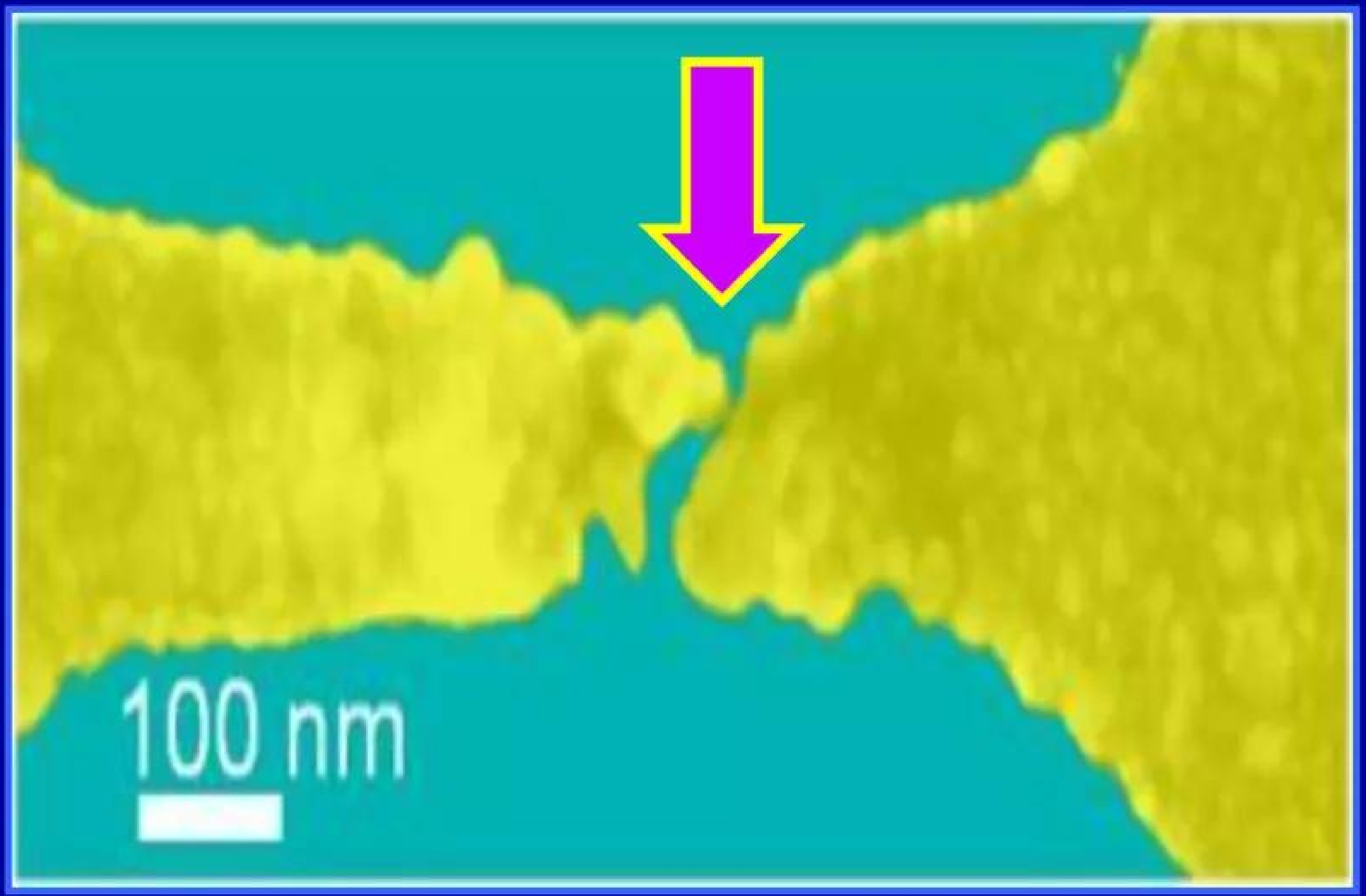
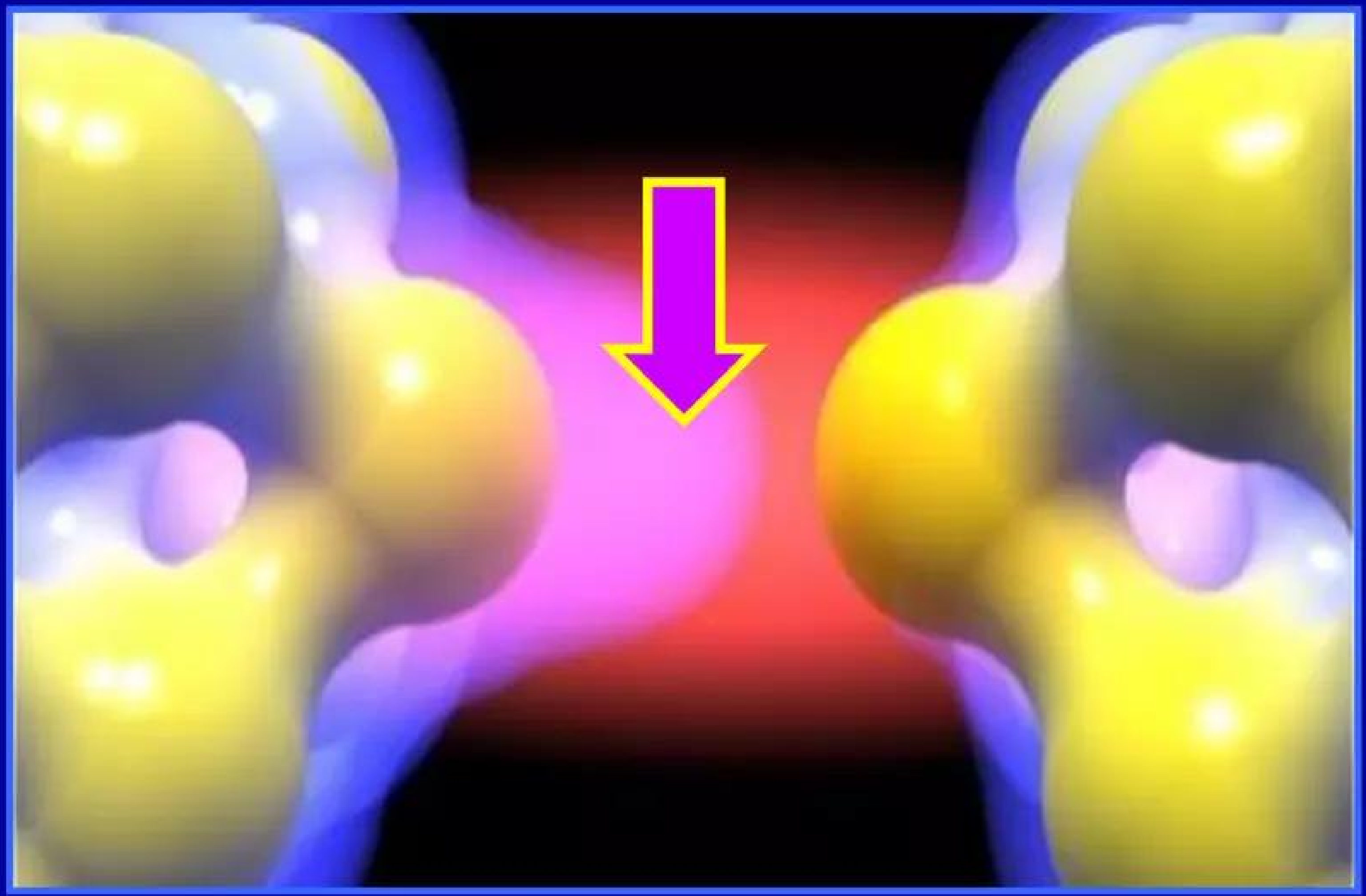
Multiple ways to provide input energy to LENR-active sites

Laser beams can energize surface plasmons found on nanostructures

Artist's rendering (right) shows how surface plasmons on the surface of a pair of nanoscale gold (Au) nanotips (SEM image to left) concentrate incident light from a commercial laser, amplifying it locally by a factor of 1,000x



Credit: Natelson Lab/Rice University



Credit: Natelson Lab/Rice University

Reference for two above images: **"Optical rectification and field enhancement in a plasmonic nanogap," D. Ward *et al.*, *Nature Nanotechnology* 5 pp. 732–736 (2010)**

"Metal nanostructures act as powerful optical antennas because collective modes ... are excited when light strikes the surface ... [their] plasmons can have evanescent electromagnetic fields ... orders of magnitude larger than ... incident electromagnetic field ... largest field enhancements ... occur in nanogaps between ... nanostructures."

Similarly: **"Extraordinary all-dielectric light enhancement over large volumes," R. Sainidou et al., *NANO Letters* 10 pp. 4450–4455 (2010)**

" ... allow us to produce arbitrarily large optical field enhancement using all dielectric structures ... measure the enhancement relative to the intensity of the incident light. ... if absorption losses are suppressed, resonant cavities can pile up light energy to create extremely intense fields ... no upper bound to the intensity enhancement factor that these structures can achieve ... [certain factors] limit it to around 4 orders of magnitude in practice."

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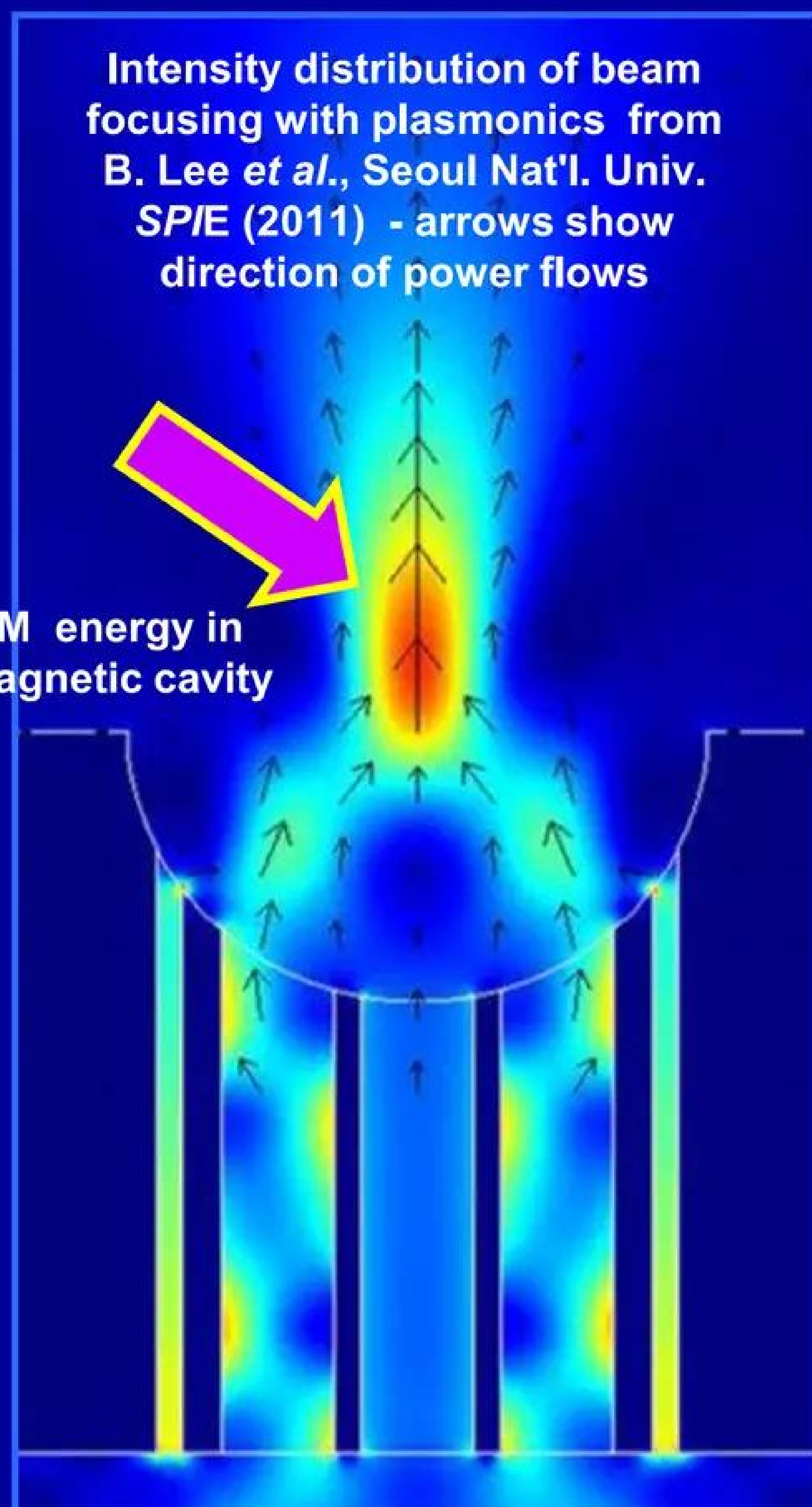
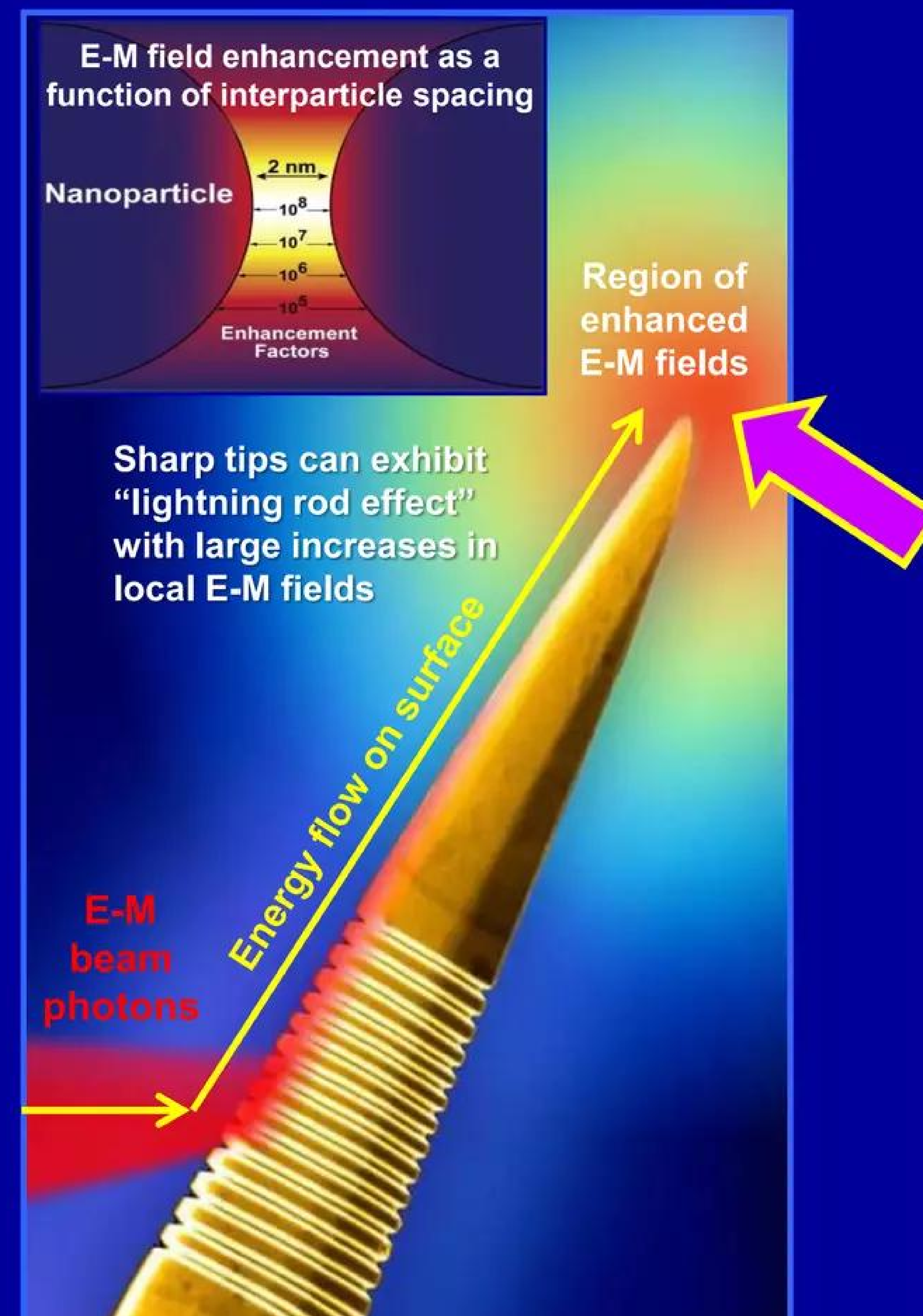
Multiple ways to provide input energy to LENR-active sites

Need to energize surface plasmons found on target nanostructures



http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf



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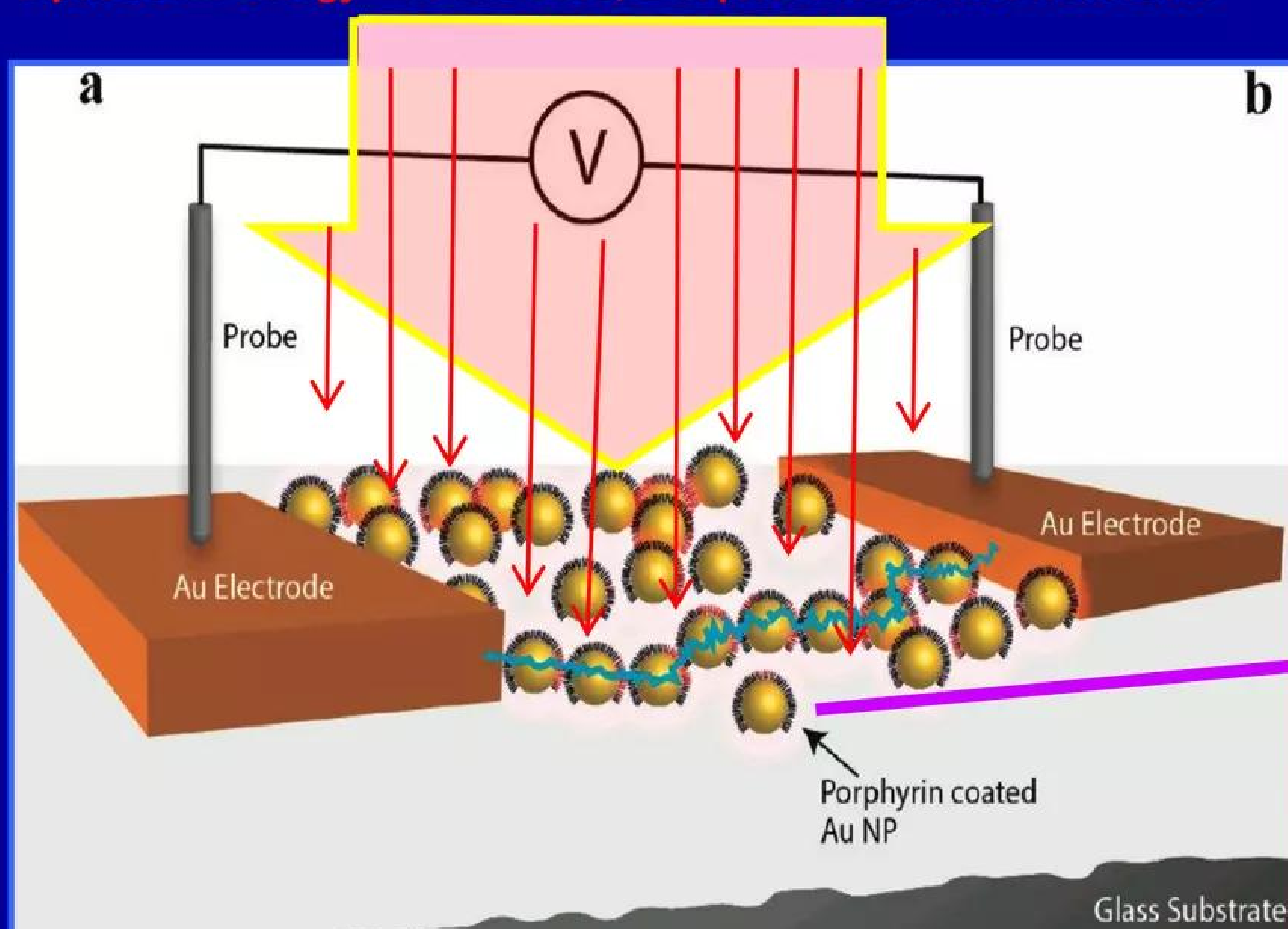
Multiple ways to provide input energy to LENR-active sites

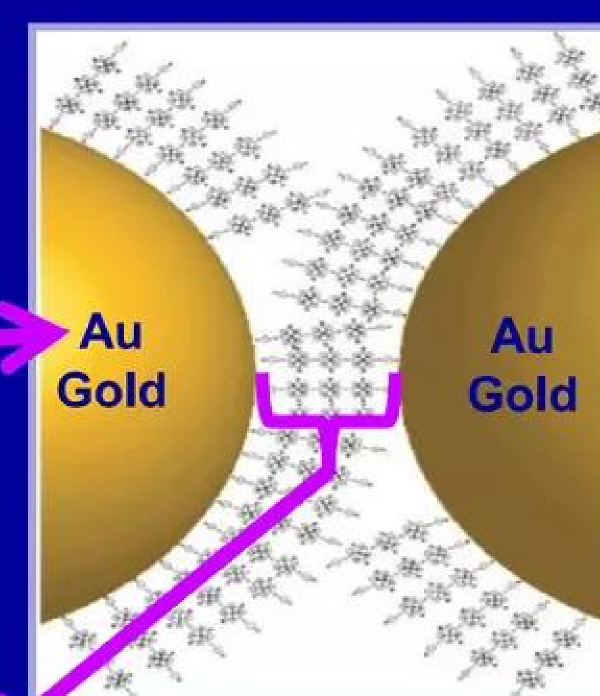
Local resonant electromagnetic coupling amongst nanostructures

Images and captions adapted from: "Plasmon-Induced Electrical Conduction in Molecular Devices," P. Banerjee *et al.*, *ACS Nano* 4 (2), pp. 1019 - 1025 (2010)
DOI: 10.1021/nn901148m
http://pubs.acs.org/doi/abs/10.1021/nn901148m

Input beam energy = in this case, E-M photons emitted from laser

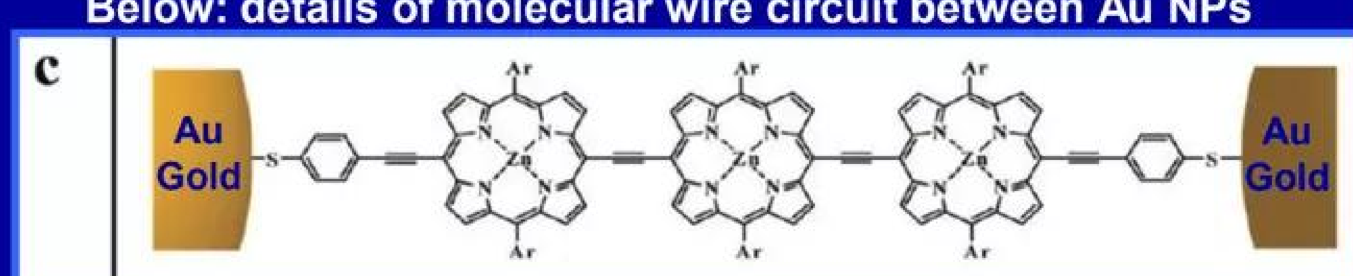


Example of Porphyrin Carbon rings coordinating Fe atom



Short chains of linked Porphyrin molecules serve as bridge wires between surfaces of adjacent metallic Au nanoparticles

Below: details of molecular wire circuit between Au NPs



Quoting directly from their abstract:

"Metal nanoparticles (NPs) respond to electromagnetic waves by creating surface plasmons (SPs), which are localized, collective oscillations of conduction electrons on the NP surface. When interparticle distances are small, SPs generated in neighboring NPs can couple to one another, creating intense fields. The coupled particles can then act as optical antennae capturing and refocusing light between them. Furthermore, a molecule linking such NPs can be affected by these interactions as well. Here, we show that by using an appropriate, highly conjugated multiporphyrin chromophoric wire to couple gold NP arrays, plasmons can be used to control electrical properties. In particular, we demonstrate that the magnitude of the observed photoconductivity of covalently interconnected plasmon-coupled NPs can be tuned independently of the optical characteristics of the molecule - a result that has significant implications for future nanoscale optoelectronic devices."

Free copy of entire paper at http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/4102/274635800055.pdf?sequence=1

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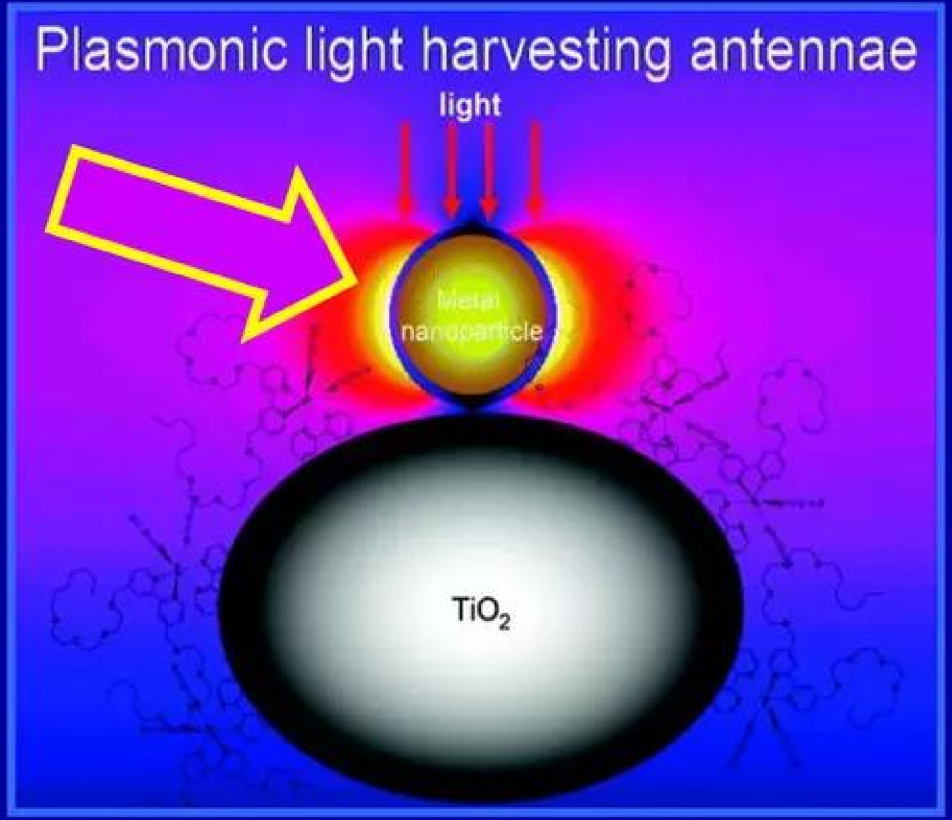
High local E-M fields needed to create heavy electrons

Surface plasmons absorb, transport, concentrate, store input energy

- ✓ Pucci *et al.* (2008): "If metal structures are exposed to electromagnetic radiation, modes of collective charge carrier motion, called plasmons, can be excited … Surface plasmons can propagate along a distance of several tens of micrometers on the surface of a film."
- ✓ "In the case of one nanoparticle, the surface plasmon is confined to the three dimensions of the nanostructure and it is then called localized surface plasmon (LSP). In this situation, the LSP resonance depends on the metallic nature (effect of the metal permittivity) and on the geometry (effect of the confinement of the electron cloud) of the nanostructure."
- ✓ "If the smallest dimension of the particle is much larger than the skin depth of the electromagnetic radiation in the metal, also real metal wires can be estimated as perfect conductors. For ideal metal objects it is assumed that the light does not penetrate into the particle. This means an infinitely large negative dielectric function. Then, antenna-like resonances occur if the length L of an infinitely thin wire matches with multiples of the wavelength λ."
- ✓ "Electromagnetic scattering of perfect conducting antennas with D smaller than the wavelength and L in the range of the wavelength is discussed in classical antenna scattering theory … It is a frequently used approximation to consider a metal nanowire as an ideal antenna. This approach has been proposed also for the modeling of nanowires in the visible spectral range …"
- ✓ "… field is enhanced at the tip of the nanowire when the excitation wavelength corresponds to an antenna mode … the end of the nanowires in a relatively sharp and abrupt surface is a perfect candidate to host a lightning rod effect ..." [N.B. - huge localized E-fields created near sharp tips]
- ✓ "… for metallic wires larger than several hundred nanometers. The increasing size of the nanoantennas makes the resonances to appear at wavelengths that present larger negative values of the dielectric function, i.e. for wavelengths well in the mid infrared portion of the spectrum in the case of micron-sized wires. It is actually this extension of the resonant behavior to micron-sized antennas what makes these structures optimal candidates for surface enhanced Raman spectroscopy (SERS) and surface-enhanced infrared absorption spectroscopy (SEIRA)."

Reference for Pucci *et al.*:

"Electromagnetic nanowire resonances for field-enhanced spectroscopy," Chap. 8 in *One-Dimensional Nanostructures,* Pucci *et al.,* Series: Lecture Notes in Nanoscale Science and Technology, V. 3, Wang, Zhiming M. (ed.), Springer pp. 178-181 (2008)



http://people.ccmr.cornell.edu/~uli/res_optics.htm

Source of above image is the Wiesner Group at Cornell University:

See: "Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles," M. Brown *et al.*, *Nano Letters* 11 (2) pp. 438 - 445 (2011)

http://pubs.acs.org/doi/abs/10.1021/nl1031106

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Plasmons help facilitate resonant electromagnetic cavities

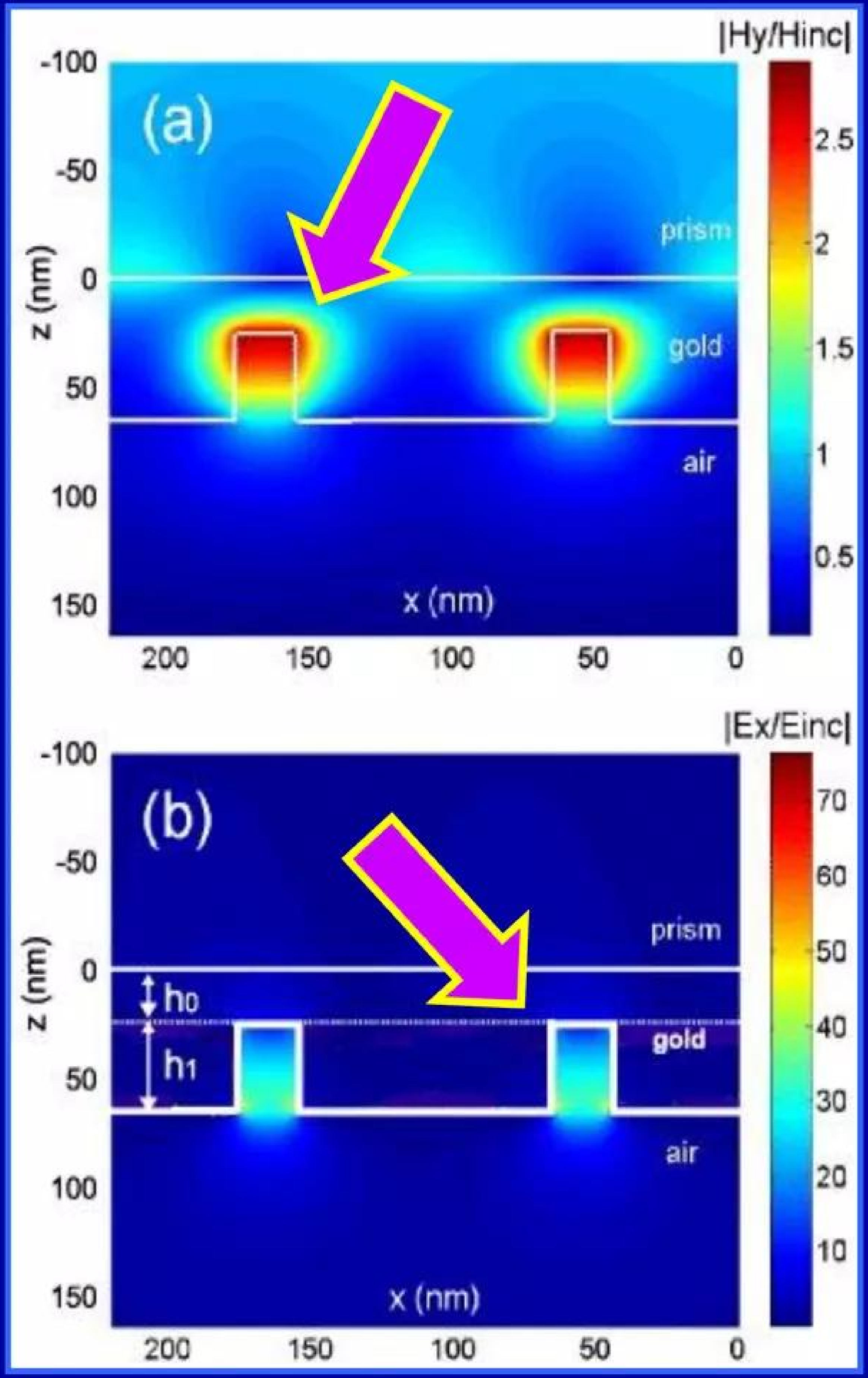
Surface plasmons absorb, transport, concentrate, store input energy

Reference:

"Enhancing reactive energy through dark cavity plasmon modes"
J. Le Perchec
***Europhysics Letters* 92 DOI: 10.1209/0295-5075/92/67006 (2010)**

Abstract:

"We present an opto-geometrical configuration in which a metallic surface having nanometer-scale grooves can be forced to efficiently resonate without emitting radiation. The structure is excited from the backside, by an evanescent wave, which allows to inhibit light re-emission and to drastically modify the quality factor of the resonance mode. The energy balance of the system, especially the imaginary part of the complex Poynting vector flux, is theoretically analysed thanks to a modal method. It is shown how the generated hot spots (coherent cavity modes of electro-static type) can store a great amount of unused reactive energy. This behaviour might thus inspire a novel use of such highly sensitive surfaces for chemical sensing."



Credit: J. Le Perchec

Also please see another reference:

"Plasmon lasers: coherent light source at molecular scales"
R-M. Ma *et al.*
***Laser & Photonics Reviews* (prelim)**
DOI: 10.1002/lpor.201100040 (2012)
http://xlab.me.berkeley.edu/publications/pdfs/185.LPR2012_Renmin.pdf

Selected quotes from article:

"Though we discuss propagating and localized surface plasmons separately, there is no clear boundary between them. Firstly, when the frequency of propagating SPPs approaches ω_{sp}, the group velocity of the electromagnetic wave tends to zero as well as the phase velocity and the field becomes more confined, so that the propagating SPPs resemble localized surface plasmons. Secondly, for extremely strong cavity feedback of SPPs, radiative scattering from the cavity is almost completely suppressed, similar to the localized surface plasmons of small metal particles ... physical size of a plasmonic laser is linked to the smallest possible surface plasmon cavity; since metallic nanoparticles down to a few nanometer in diameter can still support a localized surface plasmon, in principle, plasmonic lasers could have similar dimensions"

High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

- ✓ Producing neutrons via W-L electroweak reactions requires a threshold minimum local electric field of at least >2 x 10^{11} Volts/meter, i.e., so $e \rightarrow e^*$ --- please note that this is a typical nuclear-strength E-field seen by inner electrons in un-ionized atomic nuclei
- ✓ For example, the electric field strength at a Bohr radius, ~0.5 Angstrom, away from an isolated proton is roughly 5 x 10^{11} V/m (please see our 2006 *EPJC* or 2009 - 2010 *Primer* papers for details)
- ✓ When Born-Oppenheimer approximation breaks down on various types of surfaces, local E-M coupling between films of collectively oscillating surface plasmon electrons (e.g., on metals) or π electrons (e.g., on aromatic rings, graphene, etc.) and nearby collectively oscillating surface patches of protons or deuterons, can theoretically create an estimated electric field in the immediate vicinity of the patch on the order of 28.8 x 10^{11} V/m (Eqs. 26 and 27 in *Primer*) --- this value well-above bare minimum E-field threshold for W-L neutron production via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ electroweak reactions
- ✓ Some have expressed concerns that our theoretical electric field strength estimate may be unphysical in it being hard to exceed 2 x 10^{11} V/m in the "real world" --- such fears are groundless: local E-fields >10^{11} V/m are readily created on tiny sub-nm - μ length-scales

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High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

"Single-walled carbon nanohorns for hydrogen storage and catalyst supports"

"Electric fields within the crystal are in units of 10^{10}V/m --- scale shown in (b.) --- and illustrate the high-field areas where H_2 molecules are strongly bound"

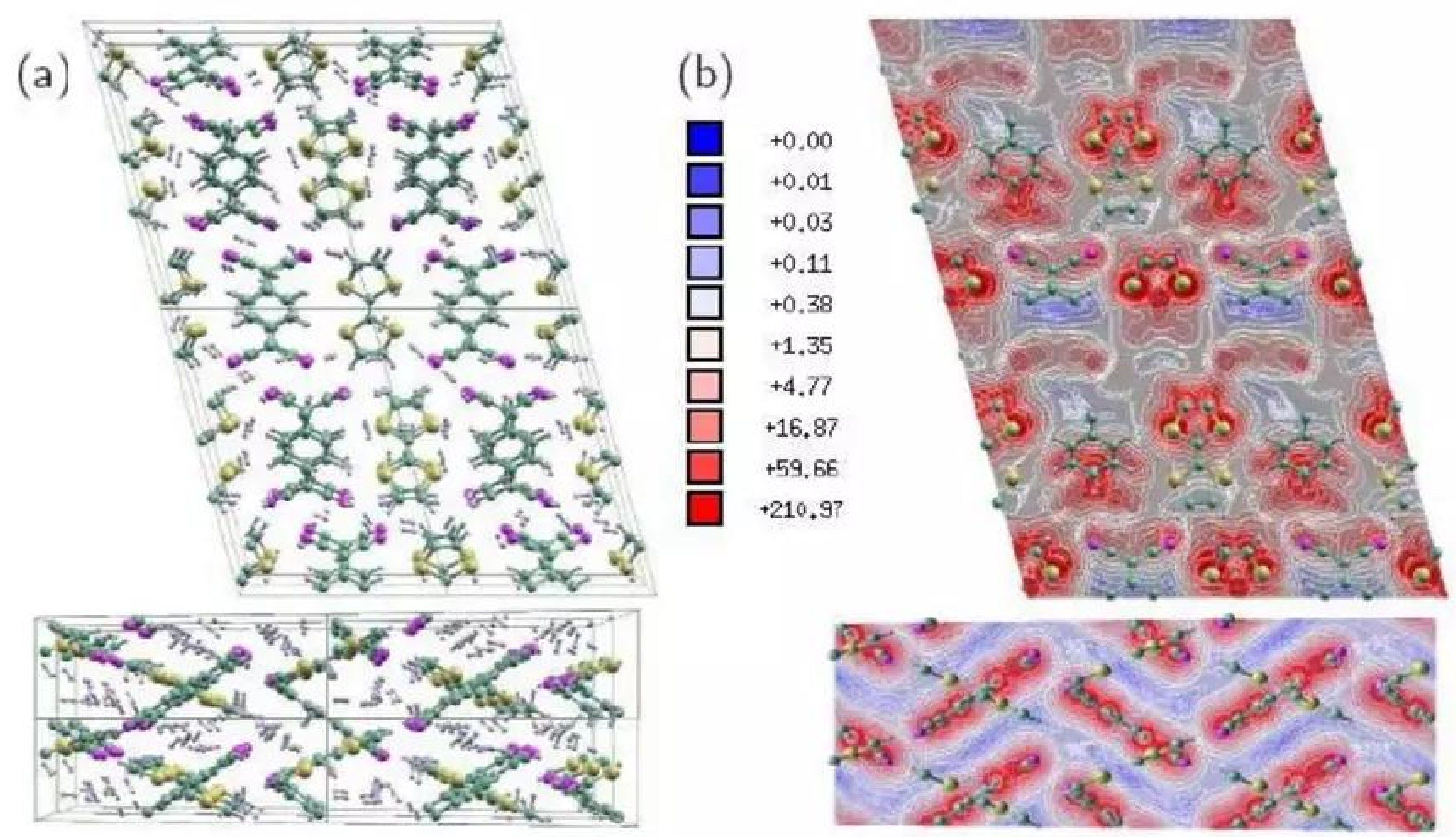
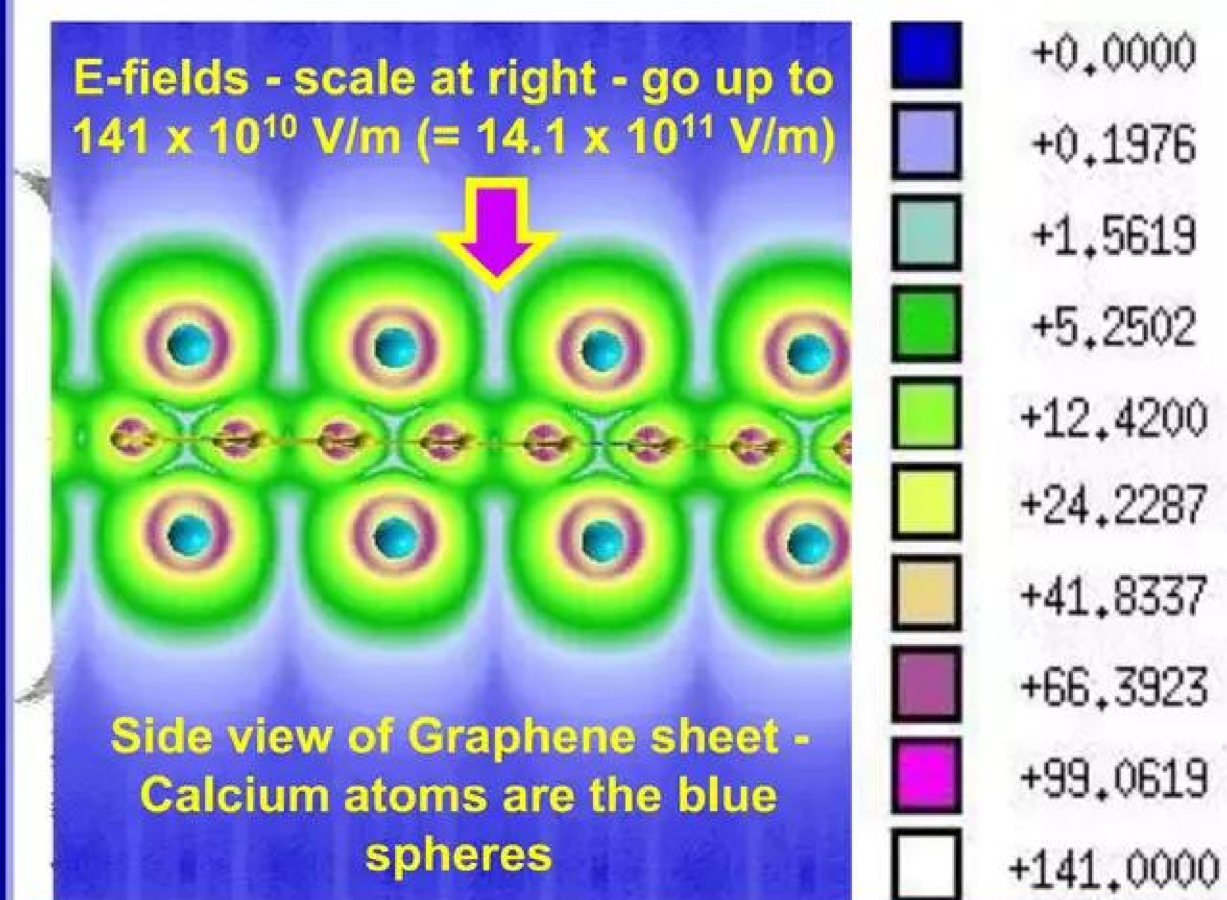


FIG. 4: (a) Crystal structure of segreggated TTF-TCNQ containing 34 H_2 in an unit cell, which corresponds to gravimetric densities 7.7 wt% and 8.2 g/l volumetric density with average H_2 binding energy 0.17 eV. Two perspective of solid structures are displayed. (b) Electric field (in the unit of 10^{10} V/m) generated in the TTF-TCNQ crystal.

Slide #18: "Proposed Future Work: Charge Transfer Organic Crystals"

π electrons on Graphene surface oscillate collectively



Slide #8: electrostatic electric fields around Calcium atoms decorating both sides of graphene sheet

"Ca atoms on both sides of graphene polarize and bind hydrogen molecules by electric field-induced polarization just as effectively as Ca atoms on just one side."

Source:

http://www.hydrogen.energy.gov/pdfs/review10/st017_geohegan_2010_p_web.pdf

Source: D. Geohegan et al., Oak Ridge National Laboratory (ORNL) , Project ID ST017 June 9, 2010

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High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

- ✓ **Size matters:** on macroscopic length scales, electric field strengths >10^{11} V/m occur mainly in extreme environments, e.g., surfaces of neutron stars (might range from ~10^{10} - 10^{13} V/m). However, on tiny sub-nm to μ length-scales, extremely high E-fields are much easier to achieve. Previous slide adapted from Geohegan *et al.* (ORNL) supports the notion that our estimate of surface patch E-fields potentially reaching 28.8 x 10^{11} V/m is quite reasonable
- ✓ Please note that for many years it has been well-known: electric fields that can exceed 10^9 V/m commonly occur in 1-3 nm regions of charge separation comprising the so-called "electrical double layer" found on surfaces of electrodes, e.g., in aqueous chemical cells - please see Wikipedia: http://en.wikipedia.org/wiki/Double_layer_(interfacial)#Electrical_double_layers
- ✓ In order to exceed W-L's key ULM neutron production threshold of >2 x 10^{11} V/m in condensed matter, **Nature needs perforce to provide us with a variety of sub-nm to *μ* local nanoenvironments in which absorbed incident E-M energy can be locally concentrated, amplified, or otherwise enhanced by factor of > ~100x 10^9 V/m, i.e., by ~10^2 or more: $e \rightarrow e^*$**
- ✓ Multiple mechanisms can provide needed levels of local E-M field strength enhancement and include: electro-geometric "lightning rod effect," electron field emission beams, and spark discharges; as well as resonant plasmonic E-M coupling processes involving metallic/metal-oxide nanoparticles, nanoantennas, open E-M (RF) cavities, SP electron nanolasers, etc.

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High local E-fields are crucial in condensed matter LENRs

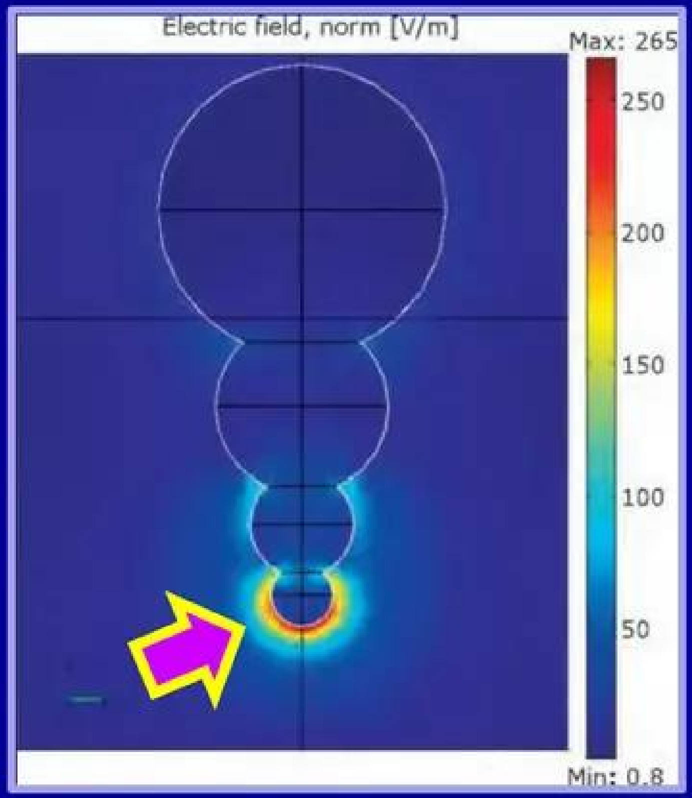
In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

Lightning rod effect, electrical arc discharges, electron field emission beams

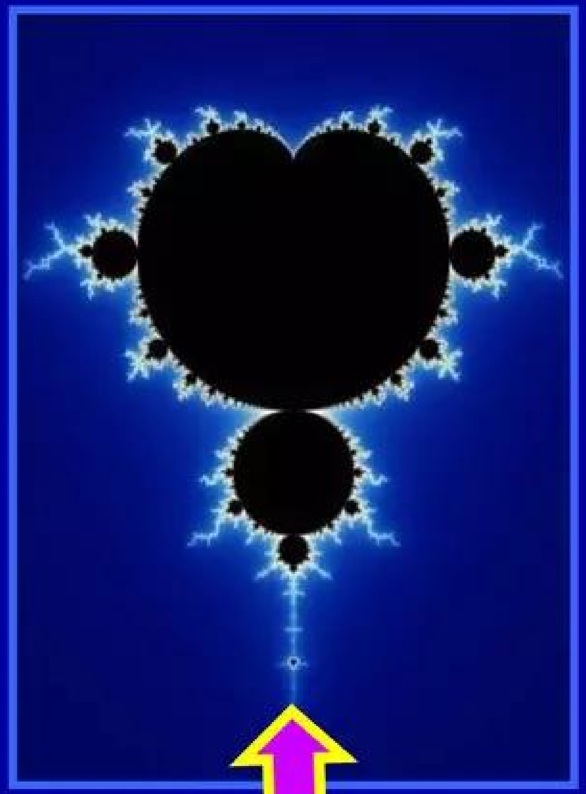
Lightning rod effect:

"Refers to the well-known fact that sharp metallic objects tend to generate very large localized [E-M] fields … This effect tends to concentrate the field lines at any sharp points of highly conductive materials. This is a shape effect, not a resonance effect, and therefore does not have any particular wavelength dependence. It may or may nor be associated with a [collective] longitudinal surface plasmon resonance …The lightning rod effect can generate extremely large field enhancements … the triangle antenna also provides an excellent illustration of [this] effect. A third technique for field enhancement is the dual-dipole effect. In this case, two resonant particles are brought close enough together to interact with each other. In the gap region between the two particles, the field can become much more intense than that from either particle separately."

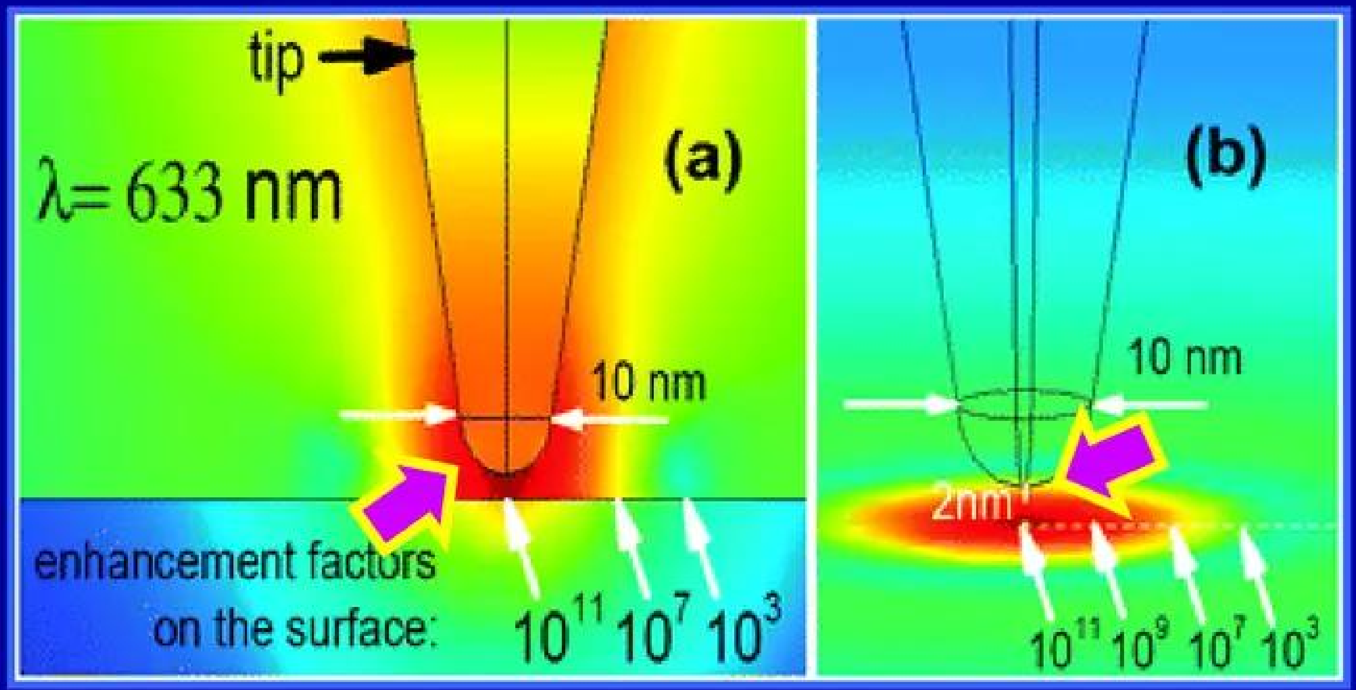
Source: "Modern Aspects of Electrochemistry 44, Modeling and Simulations II", Vol. 2, pp. 70-73, M. Schlesinger, *ed.* Springer (2009)



Electric field enhancement at nano-antenna tip: R. Kappeler *et al.*, 2007



Mandelbrot Set Classic fractal



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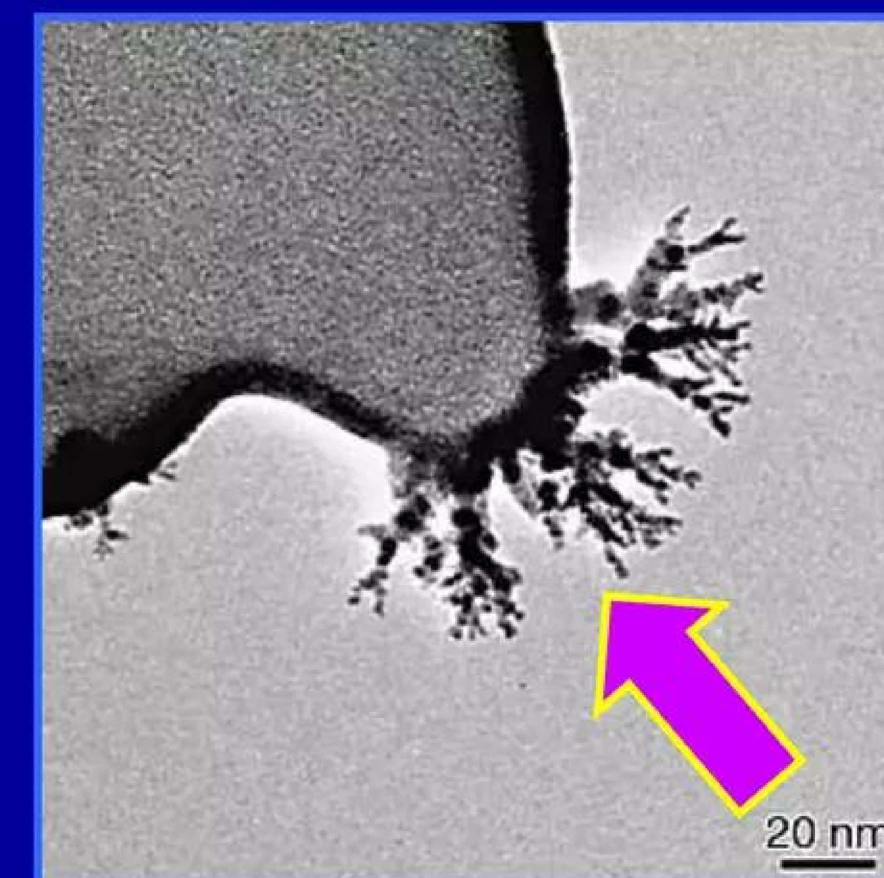
High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

Lightning rod effect, electrical arc discharges, electron field emission beams

Many fractal structures have sharp, tapered tips:

Fractals are intrinsically self-similar on all length-scales, from meters down to nanometers. As illustrated in these Figures, many types of natural fractal forms narrow-down to very sharp tips on smaller length-scales. Nanostructures with such geometries can be prone to exhibit the lightning rod effect if they happen to be comprised of electrically conductive materials



SEM image: nanodendritic Tungsten growth
Credit: Furuya and Hasegawa, CNMT - Korea

Image: macroscopic cm length-scale Copper dendrite growing in aqueous Copper Sulfate solution

Image: terrestrial lightning is on a very large length scale

Image: mm length-scale Lichtenberg Figures from electrical discharge through plastic

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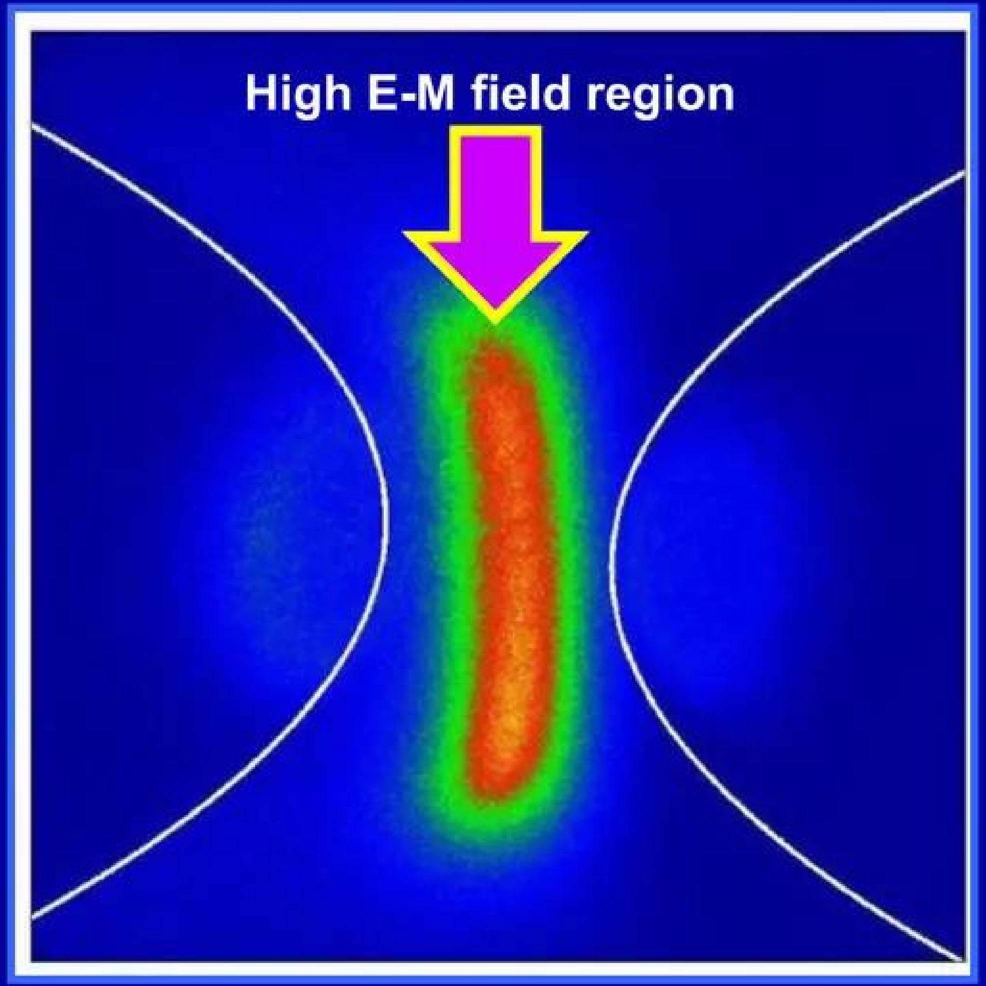
Lightning rod effect, electrical arc discharges, electron field emission beams

Electrical breakdown and arc discharges, i.e., sparks:

Although they have been studied for 200 years, in many ways electric discharges are still not all that well understood. Recent measurements (2007) of spark discharge in low-pressure Xenon gas using rapidly pulsed lasers has helped better understand the still relatively enigmatic process:

"A spark flying between a metal doorknob and your hand is an intricate chain of electrical events … researchers report the first direct measurements of the sharply changing electric fields that pave the way for a visible flash in a precisely controlled laboratory arc. Their results provided concrete detail in an area where theoretical modeling remains scanty, and may offer a way to study electrical discharges in settings ranging from plasma televisions to lightning strikes ... Whether it's a lightning bolt or the spark inside a bad switch, the process is the same: The voltage across a region of air becomes large enough to drive an electric current by creating a plasma. The process starts when a few stray electrons --- accelerated by the electric field --- knock into atoms and liberate more electrons, which continue the process. In carefully designed lab experiments the region between a pair of electrodes fills with plasma smoothly, starting at the positive end, with a wave front that sweeps quickly across to the negative end. At the leading edge of this so-called ionization front is a narrow band of enhanced electric field, according to theory and indirect experiments, but theorists only vaguely understand what determines the field's profile. Nor have experimenters been able to map the field profile directly, because inserting metal probes distorts the discharge. Researchers have tried to infer field strengths from the glow following the breakdown, but that light is feeble and only appears once the ionization is well under way.

Source: "Xenon on the verge of an electric breakdown," D. Monroe, *Physical Review Focus*, Feb. 9, 2007 URL = http://focus.aps.org/story/v19/st4



E. Wagenaars/Eindhoven Univ. of Tech

Reference: "Measurements of electric field strengths in ionization fronts during breakdown," E. Wagenaars, M. Bowden, and G. Kroesen *Physical Review Letters* 98, pp. 075002 (2007)

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In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

Lightning rod effect, electrical arc discharges, electron field emission beams

Electron field emission - in high E-M fields usually occurs prior to breakdown and discharge:

"Field emission (FE) (also known as electron field emission) is an emission of electrons induced by external electromagnetic fields. Field emission can happen from solid and liquid surfaces, or individual atoms into vacuum or open air, or result in promotion of electrons from the valence to conduction band of semiconductors. The terminology is historical because related phenomena of surface photoeffect, thermionic emission or Richardson-Dushman effect and 'cold electronic emission', i.e. the emission of electrons in strong static (or quasi-static) electric fields, were discovered and studied independently from 1880s to 1930s. When field emission is used without qualifiers it typically means the 'cold emission'."

"Field emission in pure metals occurs in high electric fields: the gradients are typically higher than 1000 volts per micron and strongly dependent upon the work function. Electron sources based on field emission have a number of applications, but it is most commonly an undesirable primary source of vacuum breakdown and electrical discharge phenomena, which engineers work to prevent."

"Field emission was explained by quantum tunneling of electrons in the late 1920s. This was one of the triumphs of the nascent quantum mechanics. The theory of field emission from bulk metals was proposed by Fowler & Nordheim. A family of approximate equations, 'Fowler-Nordheim equations', is named after them."

"In some respects, field electron emission is a paradigm example of what physicists mean by tunneling. Unfortunately, it is also a paradigm example of the intense mathematical difficulties that can arise. Simple solvable models of the tunneling barrier lead to equations (including the original 1928 Fowler-Nordheim-type equation) that get predictions of emission current density too low by a factor of 100 or more. If one inserts a more realistic barrier model into the simplest form of the Schrödinger equation, then an awkward mathematical problem arises over the resulting differential equation: it is known to be mathematically impossible in principle to solve this equation exactly in terms of the usual functions of mathematical physics, or in any simple way. To get even an approximate solution, it is necessary to use special approximate methods known in physics as 'semi-classical' or 'quasi-classical' methods. Worse, a mathematical error was made in the original application of these methods to field emission, and even the corrected theory that was put in place in the 1950s has been formally incomplete until very recently."

Source: Wikipedia article titled "Field electron emission" as of July 10, 2010 http://en.wikipedia.org/wiki/Field_electron_emission

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High local E-fields are crucial in condensed matter LENRs

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Lightning rod effect, electrical arc discharges, electron field emission beams

D. Seidman's candid comments on field emission and breakdown in a grant proposal written back in 2005:

David Seidman is the Walter P. Murphy Professor of Materials Science and Engineering at Northwestern University in Evanston, IL, and leads the Seidman Research Group at NWU's Center for Atom-Probe Tomography (NUCAPT) http://arc.nucapt.northwestern.edu/Seidman_Group

Prof. Seidman has a unique knowledge of high surface electric fields, field emission, and arc discharges as a result of his many years of work with atom-probe tomography (APT) which uses nanoscale local electric fields of 10^{10} V/m and higher to image the structure and analyze the chemical composition of surfaces on near atomic-scales (see image to right courtesy of Imago, Inc., a manufacturer of APTs)

Quoting (*ca.* 2005), "NUCAPT is among the world leaders in the field of three-dimensional atom-probe microscopy, particularly as result of the recent installation of a LEAP microscope, manufactured by Imago Scientific Instruments. Currently only three other LEAP microscopes, with a comparable performance, exist throughout the world."

Readers will find a boldness and blunt candor in Seidman's insightful remarks to follow that tend to be absent in published refereed papers

Seidman's quoted remarks were made in the context of a publicly posted 2005 grant proposal: *"Experimental study of high field limits of RF cavities"* D. Seidman & J. Norem (2005)

Please see source URL:

http://www.hep.uiuc.edu/LCRD/LCRD_UCLC_proposal_FY05/2_49_Seidman_Norem.pdf

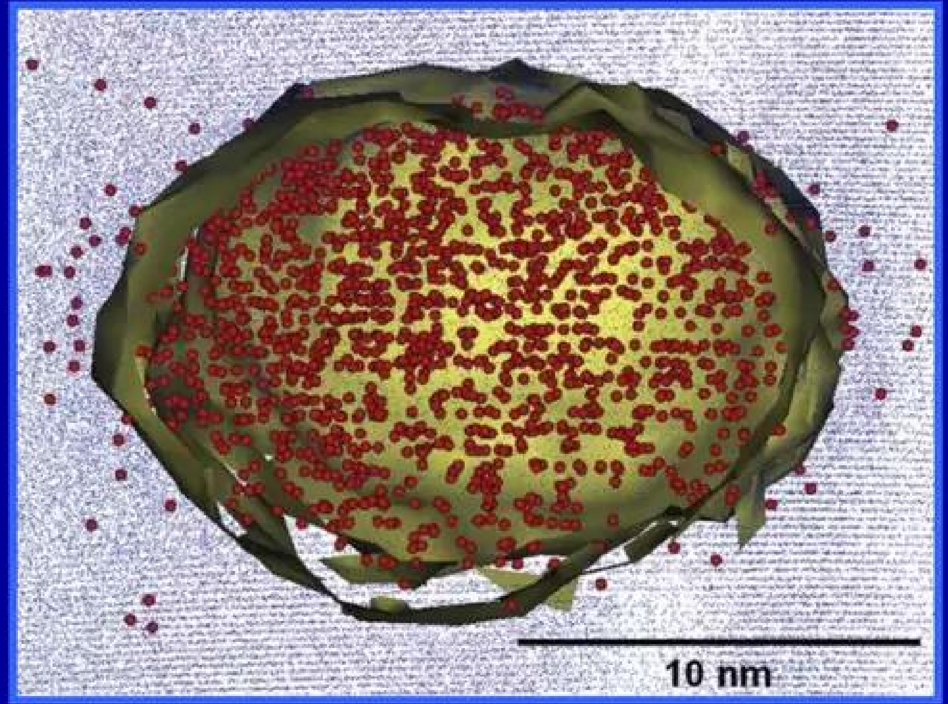

Image: Larson & Kelly, Imago, Inc., local-electrode atom probe image of ordered $L1_2$ Al_3Sc precipitate in aluminum matrix (Al – blue, Sc – red). The <200> planar spacing of the crystalline Al lattice (spacing ~0.2nm) is evident and contrasts with the <100> planar spacing (~0.4 nm) of the Al_3Sc precipitate. Alloy provided by van Dalen, Dun, and Seidman

High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

Lightning rod effect, electrical arc discharges, electron field emission beams

D. Seidman's comments *ca.* 2005 (continued):

"[Electric arc] breakdown at surfaces was discovered by Earhart & Michelson, at [the University of] Chicago, in 1900 … While checking the new 'electron' theory of gas breakdown at small distances, they discovered that there were two mechanisms present, at large distances gas breakdown dominated, and at small distances [i.e., on small length-scales] breakdown of the surface was correctly identified as the mechanism. The break point where the two mechanisms met, at atmospheric pressure, occurs at about 300 V … This was confirmed 5 years later by Hobbs and Millikan, and is consistent with modern data on vacuum breakdown."

"Although high electric fields have been used in DC and RF applications for many years, up to now there has been no fundamental agreement on the cause of breakdown in these systems … Until our work, no theoretical understanding of this process developed over the last 100 years, although many papers have been written."

"Another interesting feature of this [electrical breakdown] mechanism is that the power densities involved are enormous. The numbers can be obtained from the values we measured for field emitted currents, electric field, the emitter dimensions, and volume for transferring electromagnetic field energy into electron kinetic energy. Combining these gives, (10 GV/m)(10^{-7} m)(1 mA)/(10^{-7}m)^3 = 10^{21} W/m^3, a value that seems to be greater than all other natural effects, except perhaps Gamma Ray Bursters (GRB's). The power density is comparable to nuclear weapons. Michelson and Millikan noticed the 'hot sparks' in 1905, bought a vacuum pump, (which they didn't have), and invented vacuum ultraviolet spectroscopy. Both moved on, and did not look in detail at the mechanisms involved."

"Experimental study of high field limits of RF cavities"
D. Seidman & J. Norem (2005)

Again, please refer to source URL:

http://www.hep.uiuc.edu/LCRD/LCRD_UCLC_proposal_FY05/2_49_Seidman_Norem.pdf

In the following Slide, we modify a chart shown in Seidman & Norem's above-noted proposal to illustrate the very approximate regions of physical parameter space in which LENRs may occur if ALL the necessary preconditions that we have previously outlined are obtained. Note carefully that just the presence of very high local E-M field by itself does not guarantee that LENRs will take place at a location

Also please note that once the nuclear processes begin, power densities in LENR-active patches will go even higher for brief periods of time until local nanostructures are destroyed and LENRs temporarily cease in a given patch (occurs at time-scales on the order of <10 up to ~400 nanoseconds)

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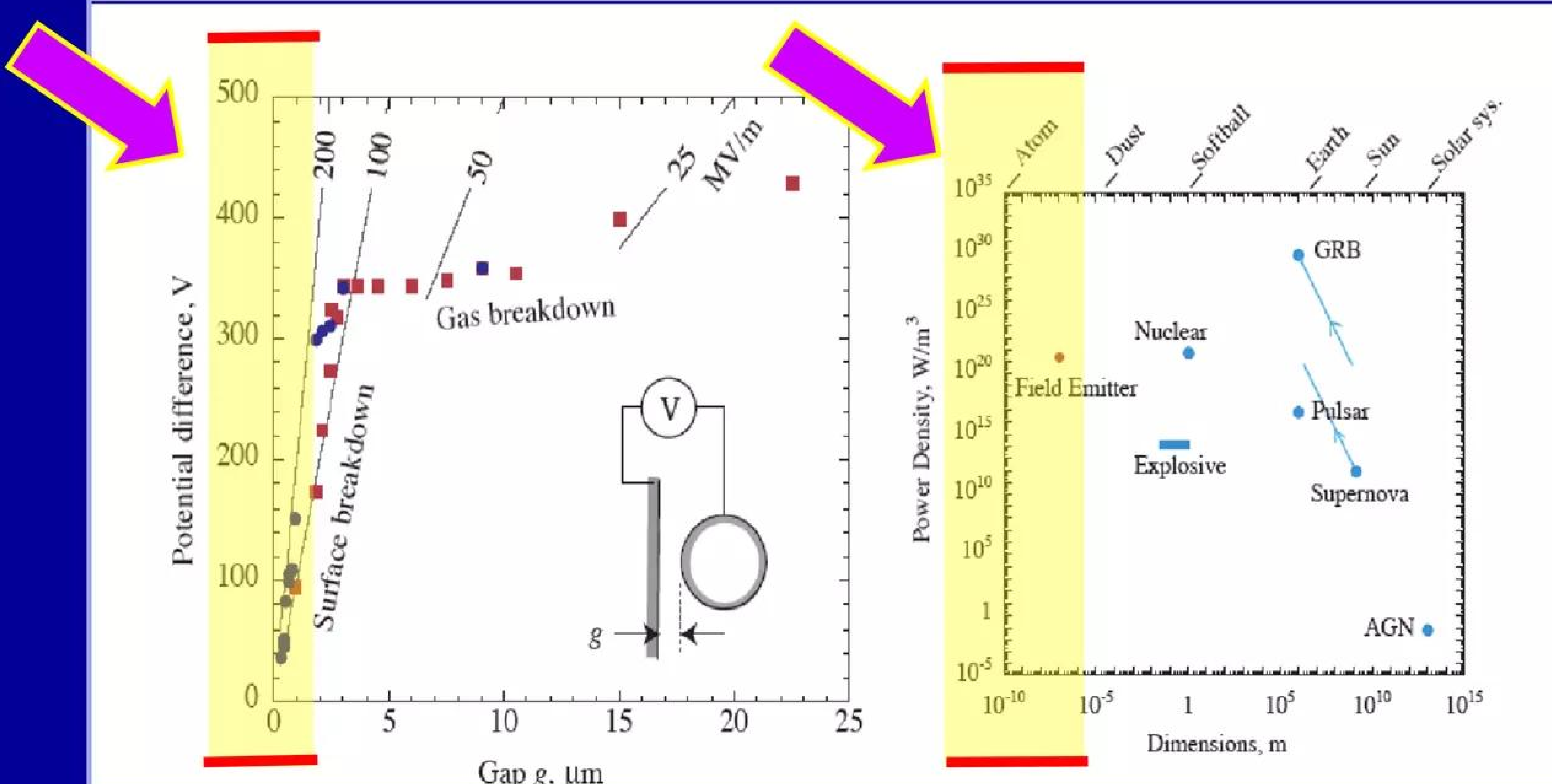
High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

Lightning rod effect, electrical arc discharges, electron field emission beams

Adapted by L. Larsen after Seidman & Norem (2005)



Lattice modification of original chart: yellow-shaded regions capped by red-colored bars are approx. regions of parameter space where LENRs may occur in condensed matter systems IF all of the necessary conditions met (please refer back to an earlier Slide)

Source: Fig. 2, pp. #3, Seidman & Norem proposal, "Experimental study of high field limits of RF cavities" (2005)

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High local E-fields are crucial in condensed matter LENRs

In W-L theory $e \rightarrow e^*$ requires nuclear-strength fields > 10^{11} V/m

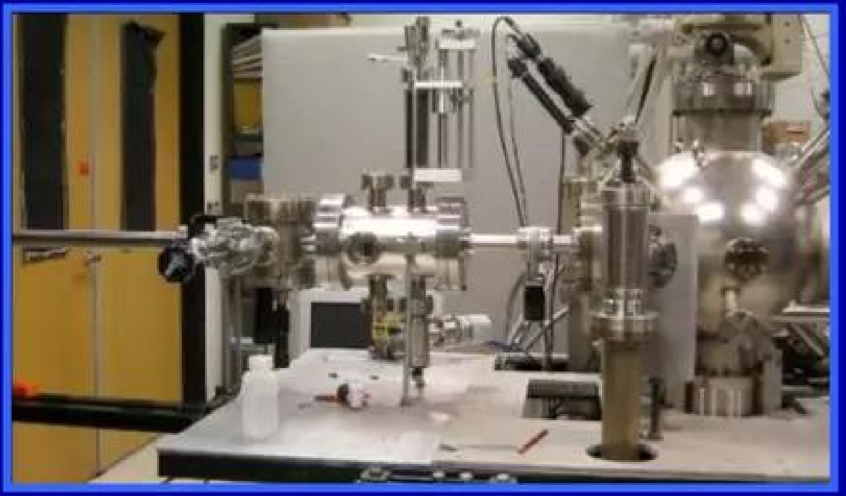
Lightning rod effect, electrical arc discharges, electron field emission beams

D. Seidman's comments *ca.* 2005 (continued):

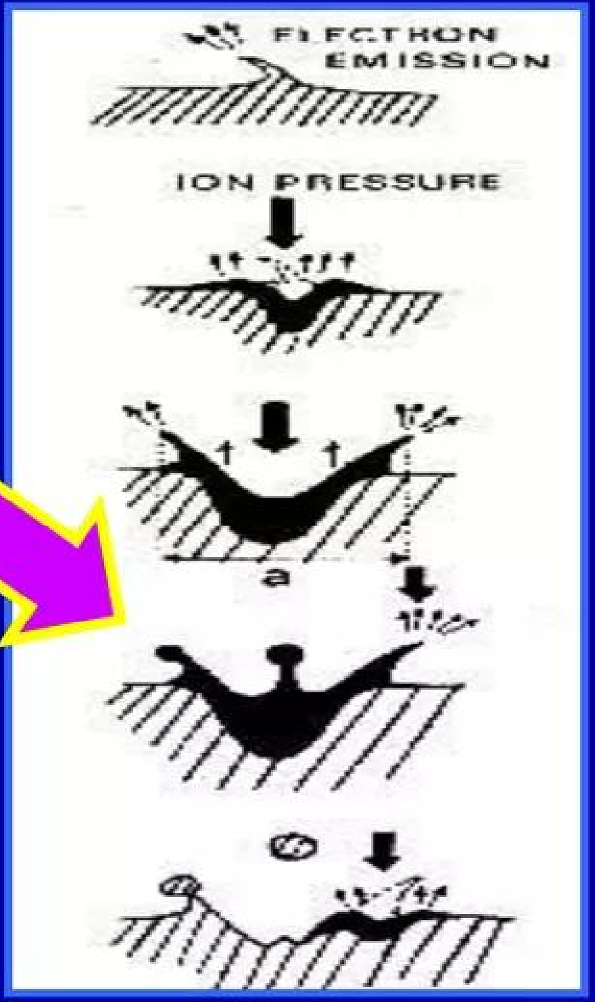
"We think we have developed a model of breakdown that explains the phenomenon in almost all environments ….The model strongly argues that breakdown events are the result of fragments or clusters breaking off of the surface and rapidly being ionized in the electron beams from the field emitter. Within the active volume, the power involved in these beams is comparable to nuclear weapons. This model is also generally in agreement with the experience with APFIM samples at the high fields used. Tiny APFIM samples operate at fields about 5 times higher than the local E field limit we postulate, but they also frequently fail, however there has been no systematic study of these failure modes."

"Combining these two ideas, however, one can conclude that: 1) this mechanism produces perhaps the highest power density commonly found in nature, and, 2) it is accessible to anyone with a wall switch or an electric light, and is used many times a day by everyone."

"While there has been extensive study of the time development of breakdown events from the first small local ionization to complete breakdown of a cavity, the trigger for breakdown, and how it was related to the metallurgy of surfaces has received very little attention until now. Our model predicts that the production of clusters and fragments is an essential component of breakdown. This is consistent with experience in Atom Probe Tomography, however there is almost no systematic data on sample failures under the high field environment used in data taking. Our previous work has been published in three refereed papers and many conference papers."



Pulsed Laser Atom Probe Microscope at NWU, Source: :Fig. 7, pp. #9, Seidman & Norem proposal (2005)



Breakdown of surface
Figure courtesy of B. Jüttner, Berlin

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Nuclear and chemical processes coexist on same surfaces

Otherwise distant realms interconnect on nm to μ length-scales

- ✓ LENR hot spots create intense local heating and variety of surface features such as craters; over time, LENR-active surfaces experience major micron-scale changes in nanostructures/composition. On LENR-active substrate surfaces, there are a myriad of different complex, nanometer- to micron-scale electromagnetic, chemical, and nuclear processes operating in parallel. LENRs involve interactions between surface plasmons, E-M fields, and many different types of nanostructures with varied geometries, surface locations relative to each other, and chemical/isotopic compositions
- ✓ To greater or lesser degrees, many of these very complex, time-varying surface interactions are electromagnetically coupled on many different physical length-scales; E-M resonances are important
- ✓ Surface plasmons and their interactions with nanostructures/nanoparticles enable physics regime that permits LENRs to occur in condensed matter systems under relatively mild macroscopic conditions (in other words, cores of stars, fission reactors, or supernovas are not required). In concert with many-body, collective Q-M effects, SPs also function as two-way transducers, effectively interconnecting the otherwise rather distant realms of chemical and nuclear energies
- ✓ Please be aware that a wide variety of complex, interrelated E-M phenomena may be occurring simultaneously in parallel in different nm to μ-scale local regions on LENR-active surfaces. Some regions may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At the same time, energy can be transferred from regions of resonant absorption or capture to other regions in which emission or consumption is taking place: e.g., photon or electron emission, and/or LENRs in which [E-M field energy] + $e^- \rightarrow e^{-*} + p^+ \rightarrow n_{ulm} + \nu$ --- in LENRs, electrons and protons (particles) are truly destroyed

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Overview of W-L theory in condensed matter systems

Weak interaction is crucially important in neutron-catalyzed LENRs

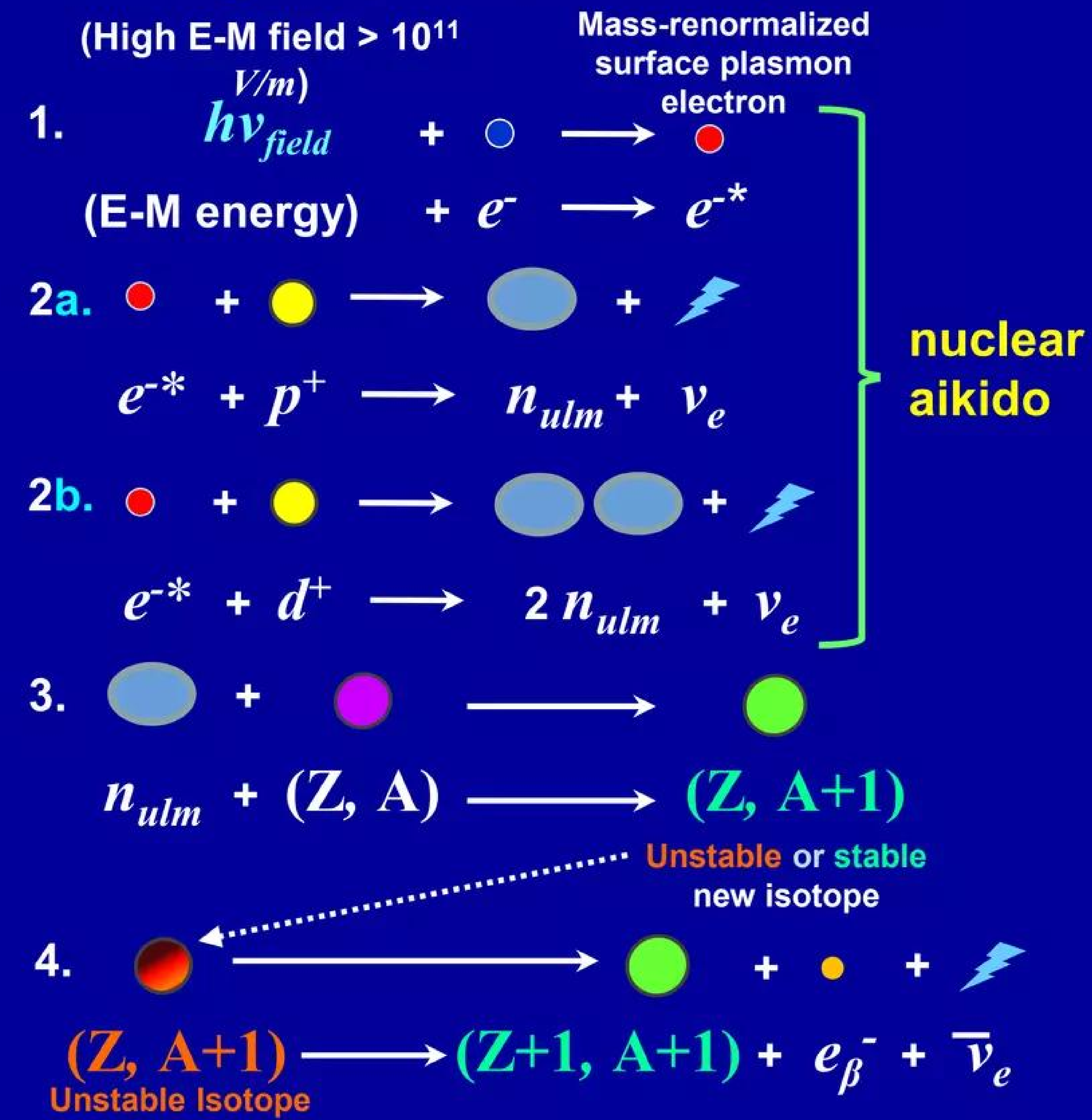
In condensed matter systems, Steps 1. through 4. occur in nm- to μ-sized patch regions on surfaces; these are called LENR-active sites

Steps 1. thru 3. are very fast: can complete in 2 to 400 nanoseconds

1. Electromagnetic (E-M) radiation on a metallic hydride surface increases mass of surface plasmon (SP) electrons
2. Heavy-mass surface plasmon electrons react directly with (a) surface protons (p^+) or (b) deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or 2 n_{ulm}, respectively) and an electron neutrino (ν_e)
3. Ultra low momentum neutrons (n_{ulm}) are captured by nearby atomic nuclei (Z, A) representing some element with charge (Z) and atomic mass (A). ULM neutron absorption produces a heavier-mass isotope (Z, A+1) via transmutation. This new isotope (Z, A+1) may itself be a stable or unstable, which will perforce eventually decay
4. Many unstable isotopes β^- decay, producing: transmuted element with increased charge (Z+1), ~same mass (A+1) as parent nucleus; β^- particle (e_β^-); and an antineutrino ν_e

Ultra low momentum neutrons are almost all captured locally (very few have time to thermalize and be detected); any gammas produced get converted directly to infrared photons (heat) by heavy electrons

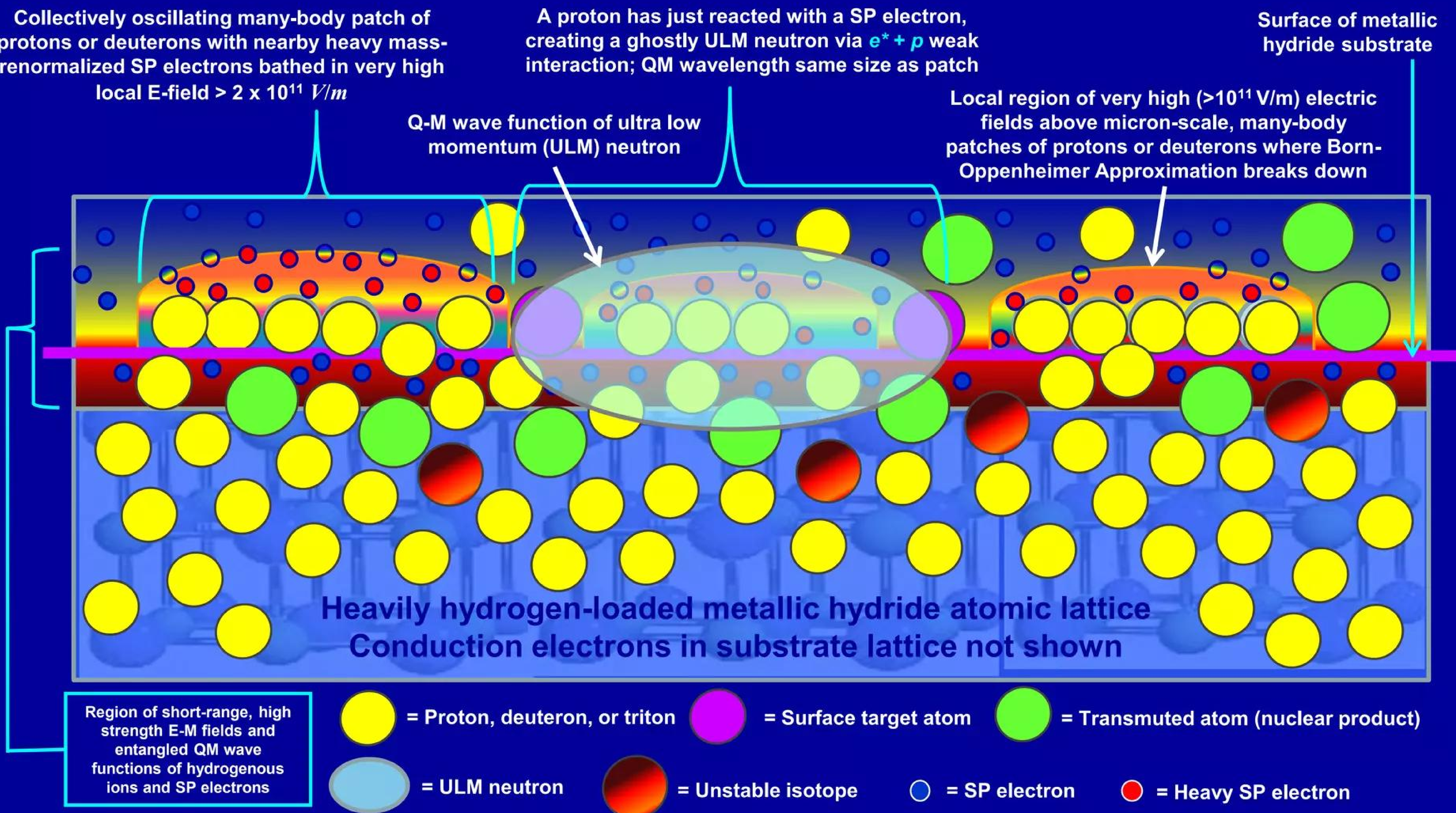
No strong interaction fusion or heavy element fission occurring below; weak interaction $e + p$ or $e + d$



Weak interaction β^- decays (shown just above), direct gamma conversion to infrared photons (not shown), and α decays (not shown) produce most of the excess heat that is calorimetrically observed in LENR systems

Chemical and nuclear realms interconnect at nm-μ scales

Is HTSC occurring at borderlands between chemical vs. nuclear realms?



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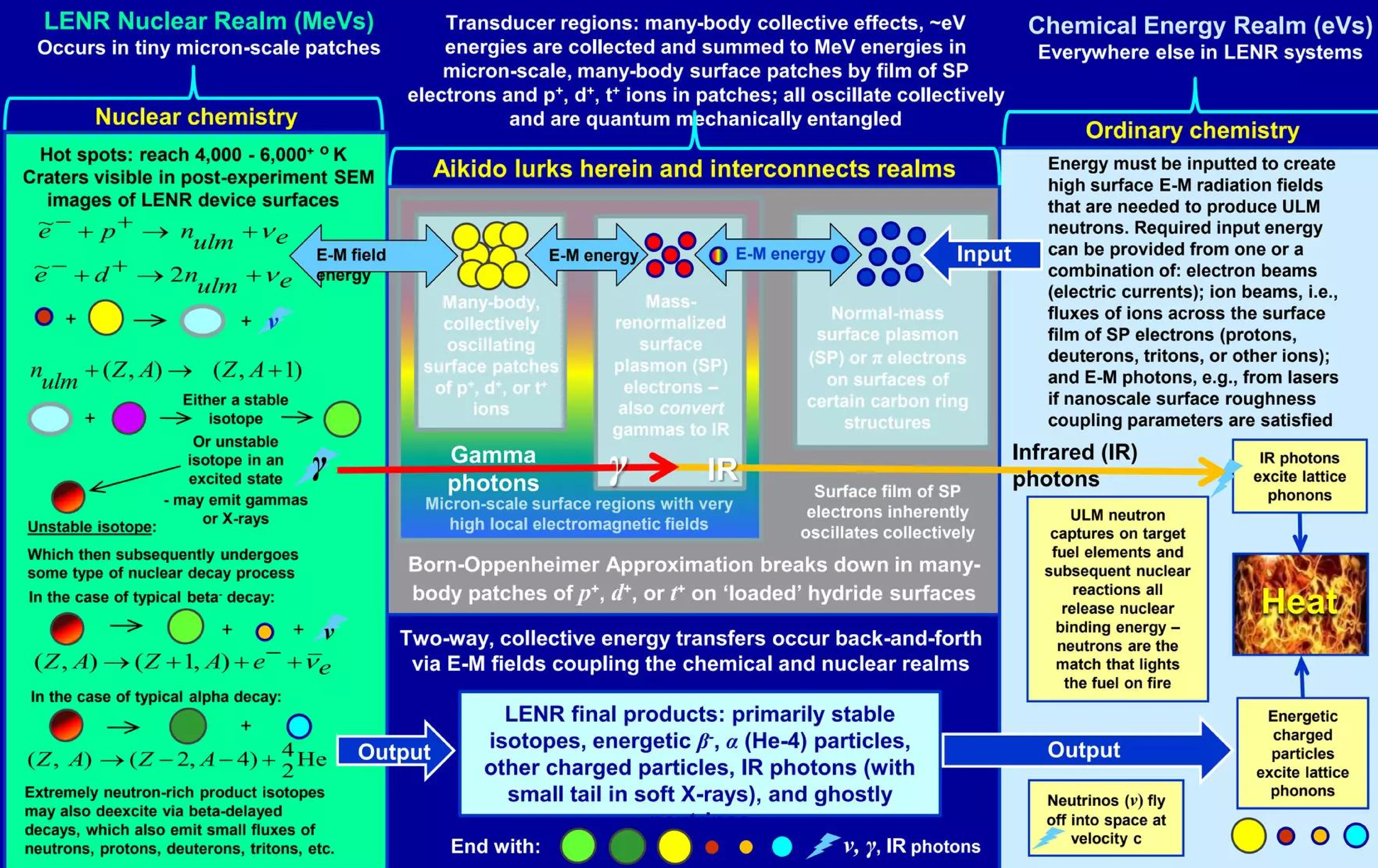
Collective many-body QM effects important in patches

Does patch become evanescent HTSC just before going nuclear?



Heavy-electron surface patches are dynamic structures

300 nanoseconds in lifetime of nm to μm-scale heavy-electron patch

- ✓ **Heavy SP electron LENR-active surface sites in condensed matter are not permanent entities. In experimental or natural systems with sufficient input energy, when conditions are just right they form spontaneously, survive for as little as 10 *ns* up to maybe several hundred nanoseconds, and then suddenly go nuclear and die, i.e., are effectively destroyed by the intense heat pulse**

- ✓ **Over time (or course of a given experiment), many cycles of birth, life, nuclear binding energy release, and death of heavy electron patches may be repeated over and over at multitudes of randomly scattered nm-to μm-sized sites found on a surface or interface; neutron-dose histories can thus vary greatly on small length-scales across entire LENR-active surfaces. Such spatial elemental/isotopic surface heterogeneity very often observed by LENR researchers with SIMS**

- ✓ **While ULM neutron production and local capture, gamma conversion to IR by heavy electrons, and subsequent nuclear decays are occurring, these tiny patches temporarily become hot spots. Their temperatures may briefly reach 4,000 - 6,000^o K or perhaps even higher. That value is roughly as high as the surface temperature of the Sun and hot enough to melt and/or even flash boil essentially all metals and alloys, including Tungsten (b.p. 5,666^o C). For a brief time, a tiny dense ball of very hot, nanodusty plasma is created. Such intense local heating events can produce various types of distinctive explosive melting features and/or comparatively deep crater-like features that are often observed in post-experiment SEM and/or SEM/EDX images of LENR device surfaces; for Zhang & Dash's image of such surface features see Slide #69 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009**

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Electroweak neutron production needs coherent protons

300 nanoseconds in lifetime of nm to μm-scale heavy-electron patch

- ✓ ULM neutron production can begin in a given many-body patch sometime after local E-field strengths exceed ~2 x 10^{11} V/m (i.e., e^{-*} mass renormalization ratio β is now greater than the minimum threshold ratio β_0) and adequately large local population of mass-renormalized heavy e^{-*} electrons have been created (enabled by local breakdown of the Born-Oppenheimer approximation in ~temporal conjunction with nonequilibrium energy inputs onto the surface)
- ✓ According to Widom-Larsen, electroweak $e^{-*} + p^+$ or $e^{-*} + d^+$ reactions occur during many-body, collectively oscillating patches of protons' brief moments of proton quantum coherence, i.e., effective entanglement within a patch; duration of such proton coherence times are on the order of attoseconds (~10^{-18} sec); these times have been measured by Chatzidimitriou-Dreismann, 2005, cited in Slide #44 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009
- ✓ Once the e^{-*} mass renormalization set-up process has completed and heavy e^{-*} electrons and p^+ protons are finally able to directly react (i.e., β now > β_0), electroweak reactions that follow only require ~10^{-19} to 10^{-22} sec to finish. Thus, while flickering proton coherence times are relatively short, electroweak reactions that produce ULM neutrons operate on even faster nuclear time-scales, allowing $e^{-*} + p^+ \rightarrow n + \gamma$ neutron production to occur at substantial rates
- ✓ When collectively produced neutrons are ULM, local neutron capture processes occur over time-horizons on the order of picoseconds (10^{-18} sec); not enough time for them to thermalize

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Many atoms compete to capture produced neutrons

300 nanoseconds in lifetime of nm to μm-scale LENR-active patch

- ✓ Note that all of the many atoms located within a 3-D region of space that encompasses a given ULM neutron's spatially extended DeBroglie wave function (whose dimensions can range from 2 nm to 100 microns) will compete with each other to capture such neutrons. ULM neutron capture is thus a decidedly many-body scattering process, not few-body scattering such as that which characterizes capture of neutrons at thermal energies in condensed matter in which the DeBroglie wavelength of a thermal neutron is on the order of ~2 Angstroms. This explains why the vast majority of produced neutrons are captured locally and not commonly detected at any energy during the course of experiments; it also clearly explains why lethal MeV-energy neutron fluxes are characteristically absent in condensed matter LENR systems

- ✓ Half-lives of the most neutron-rich, unstable beta-decaying isotopes are generally rather energetic and relatively short , often on the order of milliseconds (10^{-3} sec). For example, very neutron rich Nitrogen-23 is unstable to beta decay with a measured half-life of ~14.5 milliseconds and Q-value of ~23 MeV; see Slide #12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 Even so, ULM neutron capture processes generally occur at much faster rates than the decay rate of many beta- or alpha-unstable isotopes in LENR systems. If local ULM neutron production rates in a given patch are high enough, this large difference in rates of beta decay versus neutron capture processes means that populations of unstable, neutron-rich isotopes can potentially accumulate locally during the typically brief lifetime of an LENR-active heavy-electron patch, prior to destroying itself with an intense pulse of nuclear heat

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LENR networks are dynamic, very rapidly changing entities

300 nanoseconds in lifetime of nm to *μ*m-scale LENR-active patch

- ✓ Please note that the Q-value for neutron capture on a given beta-unstable isotope can sometimes be larger than the Q-value for the alternative *β-* decay pathway, so in addition to typically being a much faster process than competing beta decay it can also be energetically more favorable. This can further help to create local fleeting populations of short-lived neutron-rich isotopes. There is indirect experimental evidence that such neutron-rich isotopes can be produced in complex ULM neutron-catalyzed LENR nucleosynthetic (transmutation) networks that set-up and operate during the <400 ns lifetime of a patch; for example see the Carbon-seed network on Slides # 11 - 12 and especially on Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 and a Tungsten-seed network segment on Slide # 60 in http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010

- ✓ Beginning with so-called seed or target starting nuclei upon which ULM neutron captures are initiated, complex, very dynamically changing LENR nucleosynthetic networks are established in LENR-active patches. These ULM neutron-catalyzed LENR networks exist for the lifetime of the particular patch in which they were created; except for any still-decaying transmutation products that may linger, such networks typically die along with the LENR-active patch that originally gave birth to them. Seed nuclei for such networks can comprise any atoms in a substrate underlying an LENR-active patch and/or include atoms located nearby in various types of surface nanoparticles or nanostructures that are electromagnetically connected to a given heavy electron patch

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LENR networks can produce very neutron-rich isotopes

300 nanoseconds in lifetime of nm to μm-scale LENR-active patch

- ✓ For an example of a Carbon-seed LENR network please see Slides # 11 - 12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 ; for a Potassium-seed LENR network see Slide # 57 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 for a Palladium-seed LENR network see Slides # 52 - 53 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickelseed-lenr-networksapril-20-2011 for a Nickel-seed LENR network see Slides # 20 - 22 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011 ; and lastly for a Thorium-seed LENR network see Slides # 3 - 4 in http://www.slideshare.net/lewisglarsen/thoriumseed-lenr-networkfigslattice-energydec-7-2010-6177745

- ✓ Per WLT, once ULM neutron production begins at high rates, populations of unstable, very neutron-rich halo isotopes build-up locally in LENR-active patches found on ~2-D condensed matter surfaces. As explained in Slide #24 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009, such nuclei likely have somewhat retarded decays because they can have a difficult time emitting beta electrons, neutrons, or even neutrinos (all of which happen to be fermions) into locally unoccupied fermionic states. Consequently, such unstable halo nuclei may often continue capturing ULM neutrons until they finally get so neutron-rich, or a previously occupied state in the local continuum opens-up, that something breaks and spontaneous beta decay serial-cascades that eventually terminate in stable isotopes are initiated

LENR network decay chains terminate in stable isotopes

300 nanoseconds in lifetime of nm to μm-scale LENR-active patch

- ✓ Depending on half-lives of intermediate isotopes, β^- decay chain cascades can very rapidly traverse rows of the periodic table; thus, long-running LENR experiments with large ULMN fluxes can produce a broad variety of different stable elements in surprisingly short periods of time. For example, in one unrepeatable yet nonetheless spectacular experiment, Mizuno (Hokkaido University, Japan) went from Potassium (K) to Iron (Fe) in less than 2 minutes; see Slides # 54 - 59 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 For examples of beta-decay cascades see Slide #19 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011

- ✓ LENR transmutation network pathways comprising series of picosecond neutron captures interspersed with serial beta-decay cascades can release substantial amounts of nuclear binding energy, much of it in the form of usable thermal process heat; e.g., there is a multi-step Carbon-seed LENR transmutation network pathway that can release ~386 MeV over an average period of ~3.4 hours. This total energy release is comparable to fission (U-235 is ~190 MeV) but without hard MeV-energy neutron or gamma emission or production of long-lived radioactive isotopes; see Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 When neutron-creating energy inputs cease, then decay processes begin to dominate in an LENR system; namely, serial cascades (chains) of fast beta decays from unstable neutron-rich intermediates all the way down to termination in stable isotopes/elements. Importantly, few long-lived radioisotopes would remain after these rapid decay processes complete. This is precisely why LENR-active patches have a strong tendency to produce stable isotopes as end-products, thus avoiding hot radioactive wastes

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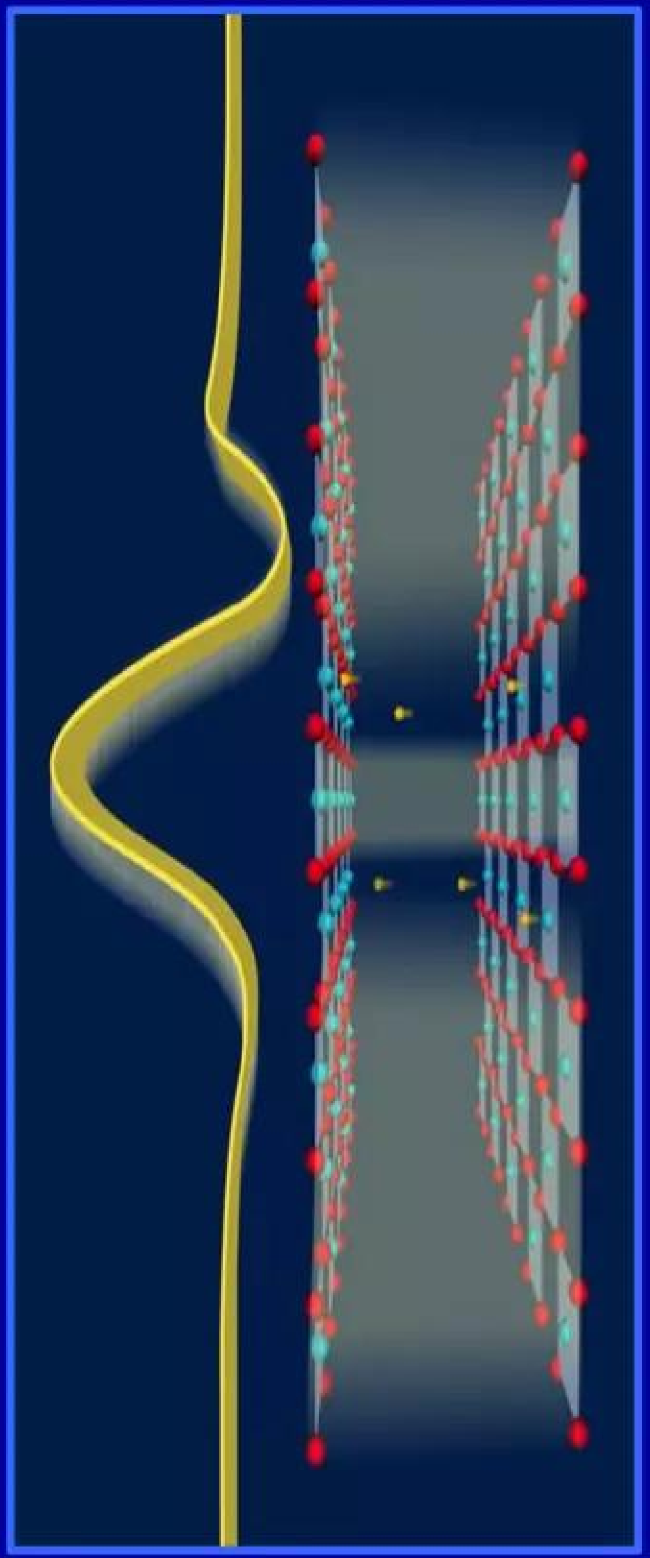
Any telltale signs of LENR-active patches post-experiment?

SEMs see craters; SIMS/EDX can see new elements or isotopic shifts

Mass spectroscopy/EDX are excellent tools for detecting LENR products:

- ✓ By early to mid-1990s, some LENR researchers located at smattering of major universities and national laboratories in Japan, Russia, Italy, and the US were already doing competent before-and-after analyses of experimental LENR devices using various types of mass spectroscopy and (mainly at ICCF conferences) reporting appearance of many new elements not initially present at the beginning of experiments and/or substantial isotopic shifts in stable isotopes of elements initially present that could not reasonably be explained by contamination and/or action of prosaic chemical isotopic fractionation processes

- ✓ Some of those LENR researchers subsequently began using SIMS to assay isotopes post-experiment and were occasionally able to spatially correlate elemental or isotopic anomalies with distinctive morphological features observed on post-experiment metallic device surfaces: unusual structures found at such locations often consisted of micron-scale crater-like microstructures and other odd morphologies indicative of locally explosive flash melting or metal-boiling events. Indeed, it was Prof. George Miley's (Dept. of Nuclear Engineering, Univ. of Illinois at Urban-Champaign) distinctive 5-peak Ni/H_2O transmutation product mass-spectrum published in 1996 (mostly SIMS and neutron activation analyses data) that convinced the author to begin looking seriously into LENRs in mid-1997



Source: "Bi-directional ultrafast electric-field gating of interlayer charge transport in a cuprate superconductor," A. Dienst *et al.*, *Nature Photonics* 5 pp. 485 - 488 (2011)

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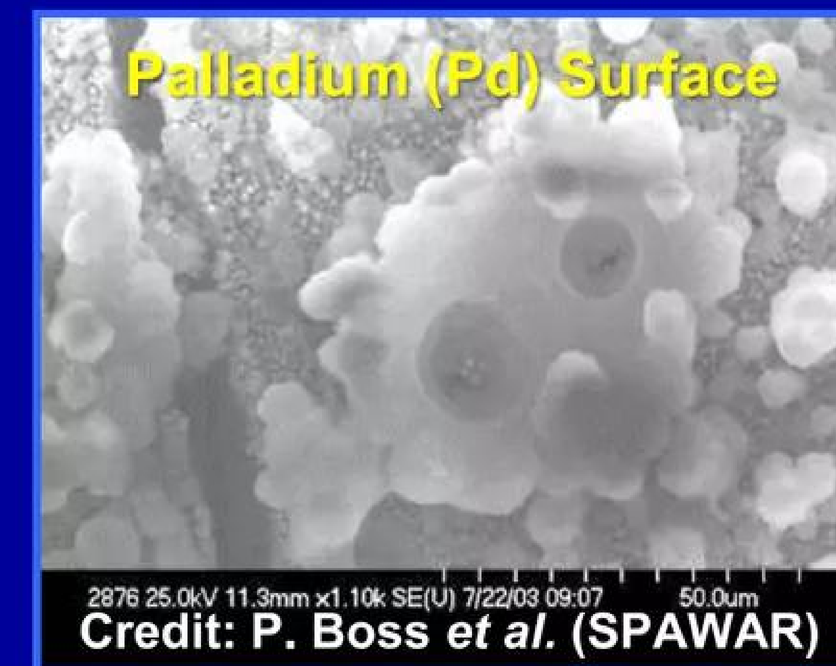
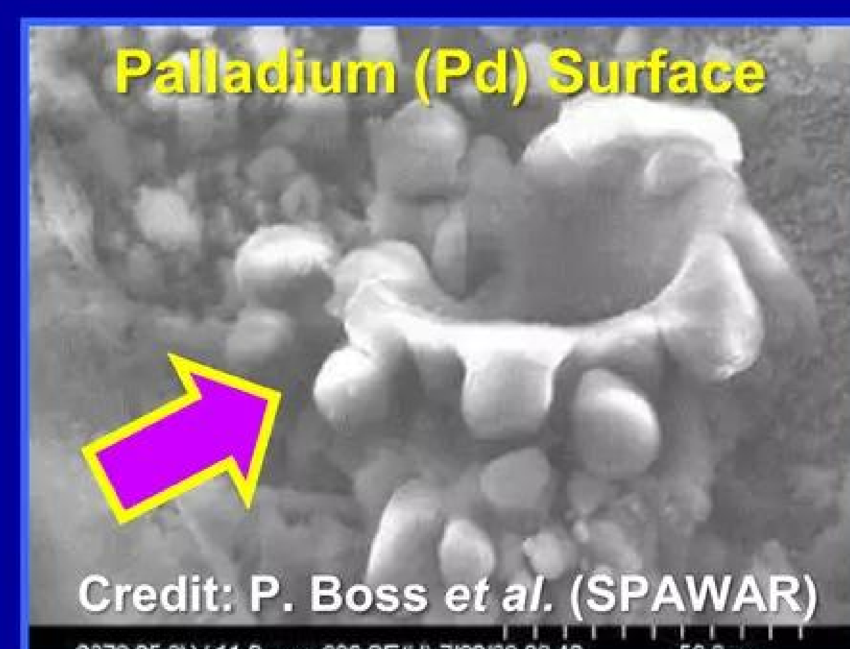
Post-experiment SEM images of LENR device surfaces

Local melting and crater-like features suggest intense heat production





Note: besides the examples shown here, nanostructures created by LENRs display an extremely varied array of different morphologies and can range in size from just several nanometers all the way up to ~100 microns or more; Palladium b.p. = 2,970^{o}C

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LENR transmutation products observed near craters

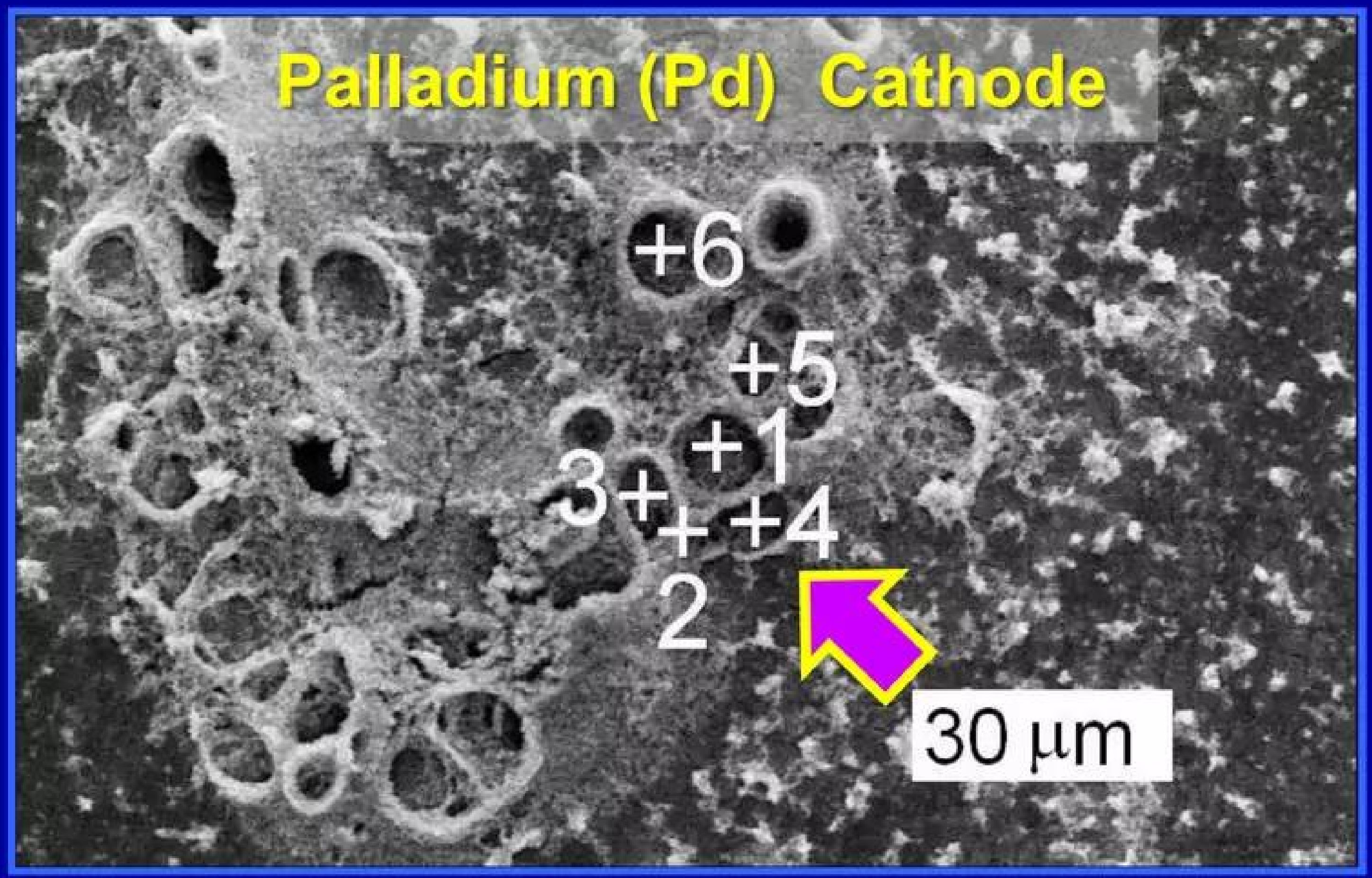
Zhang & Dash (2007) reported transmutation of Pd substrate into Ag

Following nuclear reactions would explain some reported observations in these experiments:

neutron capture / beta decay

Stable Pd + n $\longrightarrow$ **unstable neutron-rich Pd isotopes** $\longrightarrow$ **Stable Ag isotopes**

LENRs: Zhang & Dash (2007) - Fig. 8



Note: Pd b.p. = 2,970^{o}C

LENRs: Zhang & Dash (2007) - Fig. 9

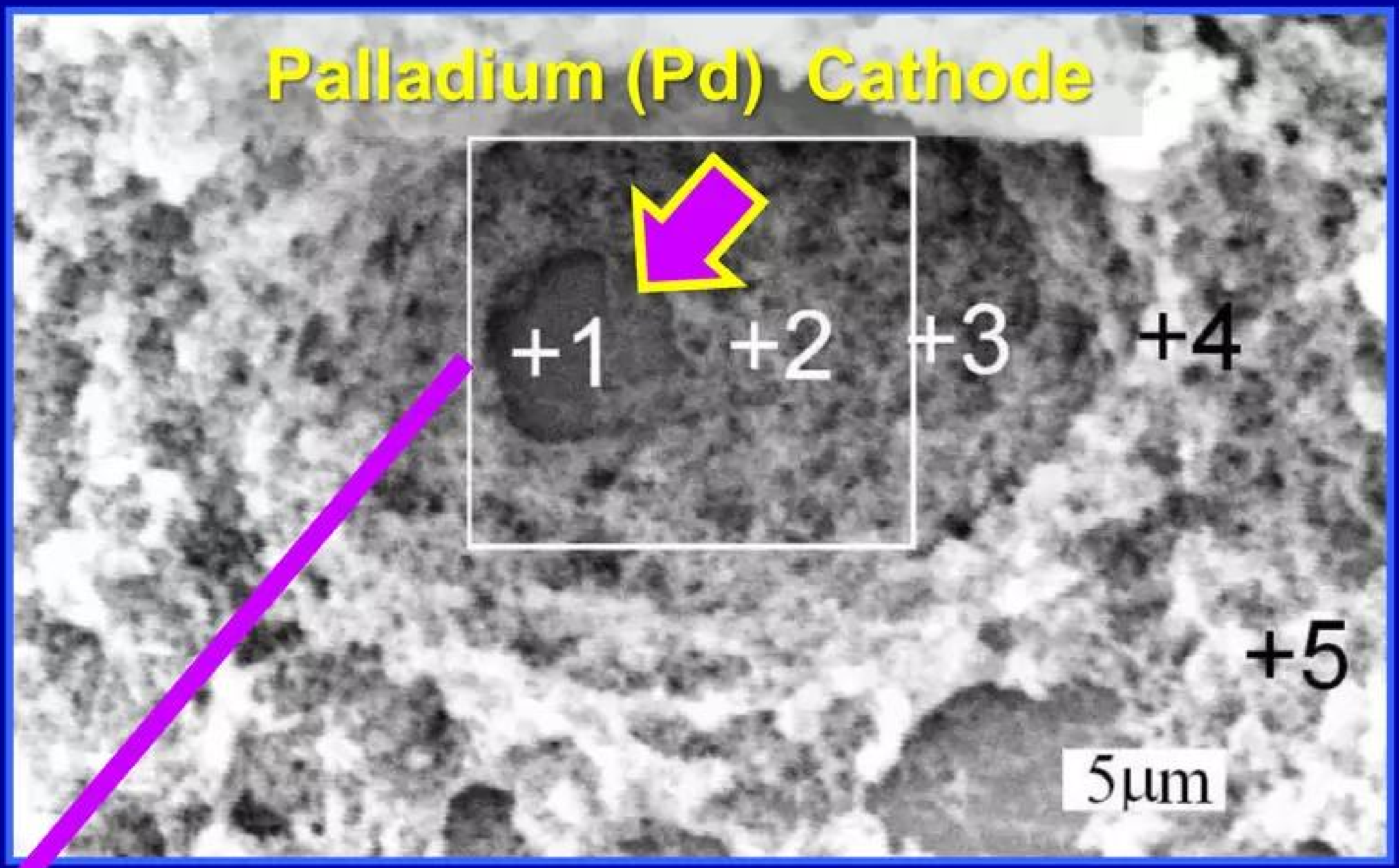


Fig. 9. SEM picture of crater at another time. SEM No.WS060607Pd-H-CC-i2-2kX

Quoting: **"The most common finding is that Silver occurs in craters, such as those shown in Fig. 8. These craters with rims almost certainly formed during electrolysis. Pt deposition was concentrated on these protruding rims."**

Zhang and Dash: Table IX. Relative atomic percent concentrations of Silver (Ag) in area and spots shown in Fig. 9

Spot #	wa*	area**	+1	+2	+3	+4	+5
Ag/(Pd+Ag)	1.2 +/- 0.5	5.6 +/- 0.4	6.8 +/- 0.4	5.6 +/- 0.3	6.3 +/- 0.4	3.6 +/- 0.6	1.2 +/- 0.5

*wa = whole entire area comprising image in Fig. 9

** area = delimited by the white square outlined in Fig. 9

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LENR transmutation products observed near craters

Zhang & Dash (2007) reported transmutation of Pd substrate into Ag

Ag and Ni were not present when experiments began; chemical processes cannot create new elements

Reference:

"Excess heat reproducibility and evidence of anomalous elements after electrolysis in $Pd/D_2O + H_2SO_4$ electrolytic cells"

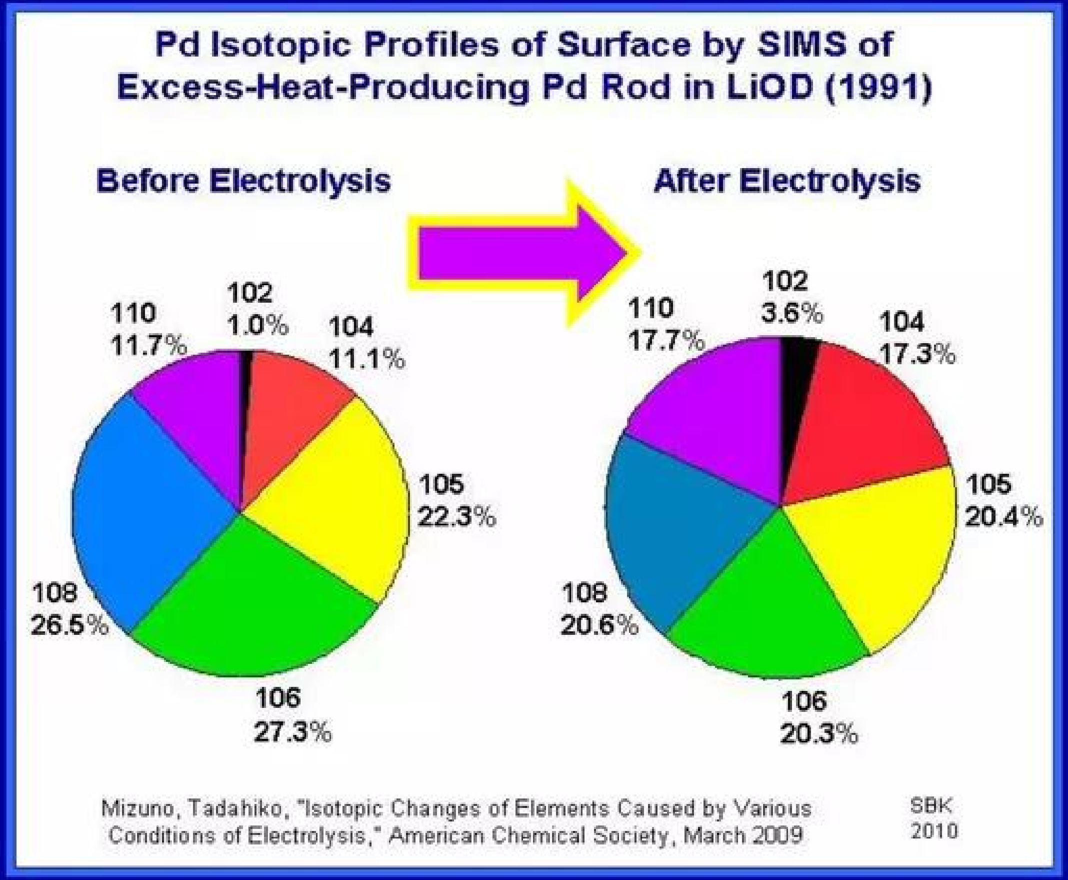
W. Zhang and J. Dash

Presented at the 13th International Conference on Condensed Matter Nuclear Science, Sochi, Russia (2007)

Free copy of above paper available at:

http://www.lenr-canr.org/acrobat/ZhangWSexcessheat.pdf

T. Mizuno & H. Kozima - ACS (March 2009):



Quoting from discussion of Fig. 10: "Ni was listed as 'not detected' in the chemical analysis provided by the vendor of the Pd foil. It is very unlikely to have resulted from the cold rolling process or from electrodeposition because it is highly localized near one corner of the cathode. If it is the result of either contamination from the rolling mill or from electroplating it should not be highly localized on only one corner of the cathode. It could not have resulted from SEM systems because the stainless steel components of the SEM chamber also contain Fe and Cr. Fe and/or Cr are not present in any of the spectra. The SEM does not have components made of pure Ni. Therefore, the origin of the Ni is not known."

Zhang & Dash (2007) --- Fig. 10. SEM picture of region #2 in Fig. 4(b). SEM No.WS060424Pd-H-CC-i2-150X

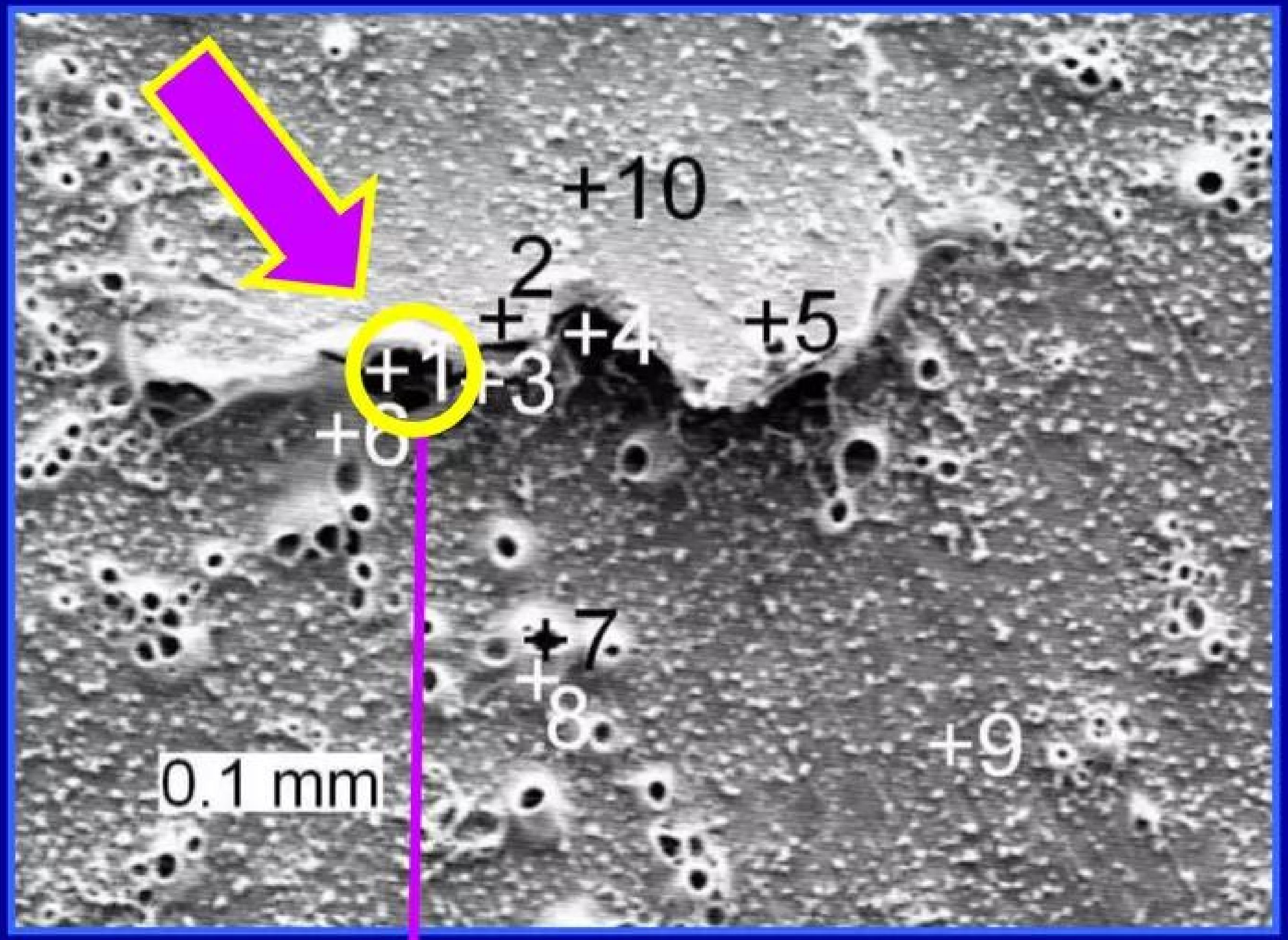
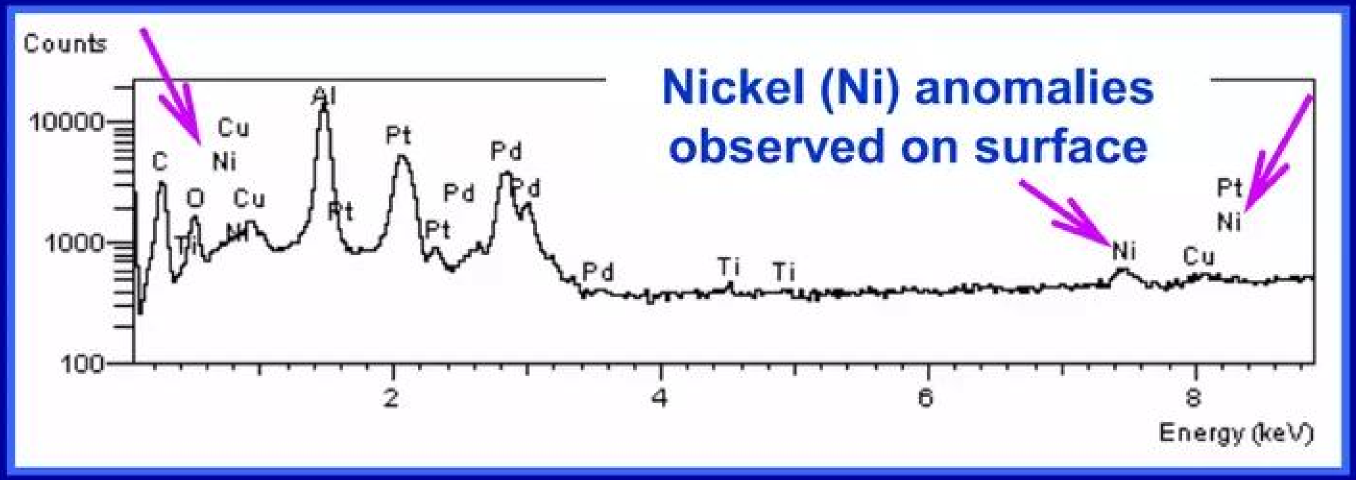


Fig. 11. Characteristic X-ray spectrum of Spot #1 in Fig. 10



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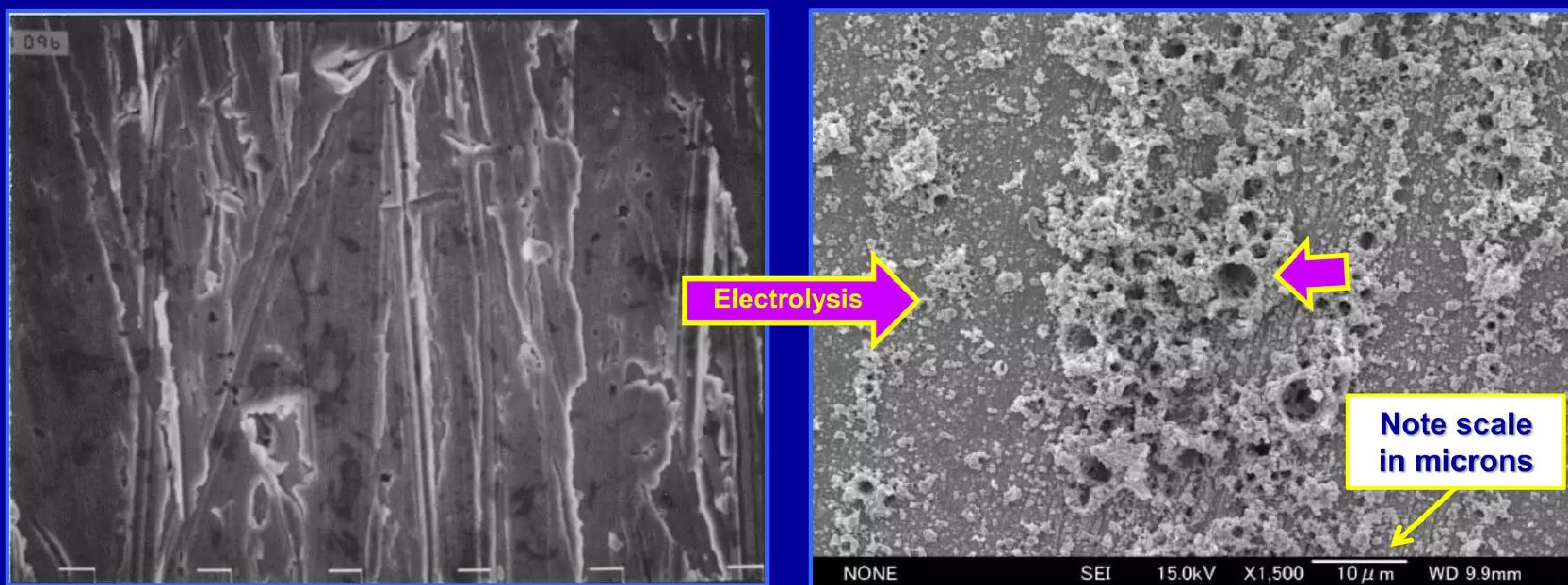
Before and after SEM images of Pd electrode surface

Mizuno *et al*. reported on new experiments at ICCF-17 (2012)

Please note extensive development of crater-like blow-out structures on metallic surface

Before: relatively smooth surface | **After: rugged terrain on micron-scales**



Quoting Slide #5 caption in ICCF-17 presentation: "These photo are the Pd electrode before and after the electrolysis. Electrolysis was conducted for a long time, several day or several week. Typical current density was 20mA/cm^2. Here, you see the metal particle (100 nm or less) on the surface after electrolysis. Some of them are less than 10 nano-meter of size."

Source: 41-slide ICCF-17 conference (Aug. 12-17, 2012, Daejeon, Korea) presentation titled, "Theoretical Analysis of Chemically Assisted Nuclear Reactions (CANR) in Nanoparticles," T. Mizuno, M. Okuyama, Y. Ishikawa, and T. Oheki

Copy of slides available at: http://newenergytimes.com/v2/conferences/2012/ICCF17/ICCF-17-Mizuno-Theoretical-Analysis-Slides.pdf

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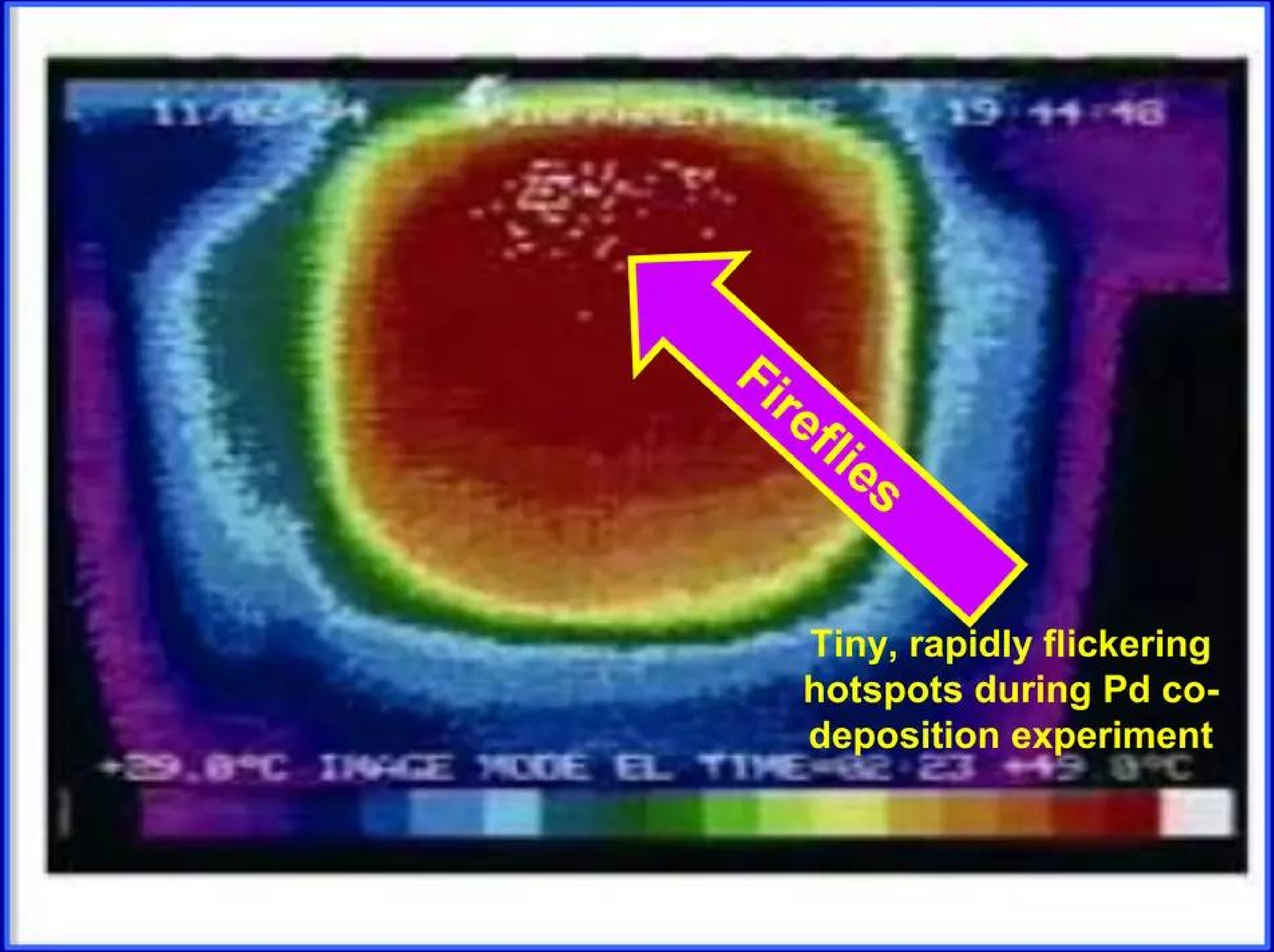
U.S. Navy imaged LENR-active cathode surface with IR

SPAWAR's high-speed IR camera saw firefly-like hotspots in infrared



Readers are urged to view SPAWAR's (P. Boss *et al.*) fascinating short video clip: it is very reminiscent of high-speed flickering of thousands of tiny fireflies in a field at night

2005 - U.S. Navy SPAWAR San Diego LENR Research Lab: Infrared Measurements
Jan 13, 2009 - 2 min - Uploaded by Steven Krivit
http://www.youtube.com/watch?v=Pb9V_qFKf2M&feature=player_embedded

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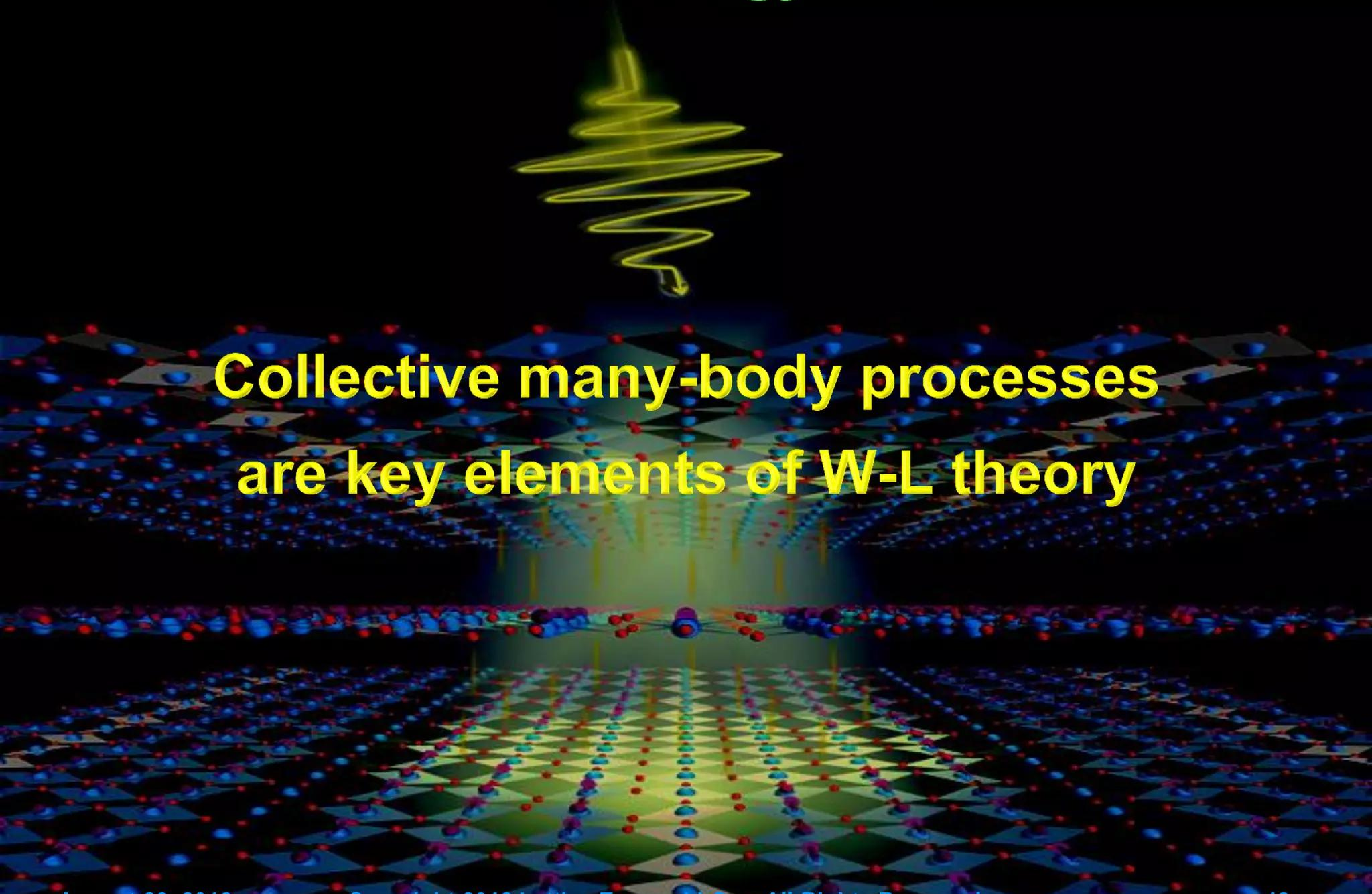

Collective many-body processes are key elements of W-L theory

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Many-body collective Q-M effects are widespread in Nature

Robert Laughlin (Stanford) argued the case for this in a book

Such effects enable star-like nuclear processes to occur in condensed matter systems

"I am increasingly persuaded that all physical law we know about has collective origins, not just some of it.“

"… I think a good case can be made that science has now moved from an Age of Reductionism to an Age of Emergence, a time when the search for ultimate causes of things shifts from the behavior of parts to the behavior of the collective ….. Over time, careful quantitative study of microscopic parts has revealed that at the primitive level at least, collective principles of organization are not just a quaint sideshow but everything --- the true essence of physical law, including perhaps the most fundamental laws we know … nature is now revealed to be an enormous tower of truths, each descending from its parent, and then transcending that parent, as the scale of measurement increases."

"Like Columbus or Marco Polo, we set out to explore a new country but instead discovered a new world."

Robert Laughlin, *A Different Universe - Reinventing Physics from the Bottom Down,* Basic Books, 2005, pp. xv and 208

Lattice Energy LLC

Many-body collective Q-M effects are widespread in Nature

Born-Oppenheimer breakdown is important in condensed matter

Phenomenon is well-established and measured experimentally:

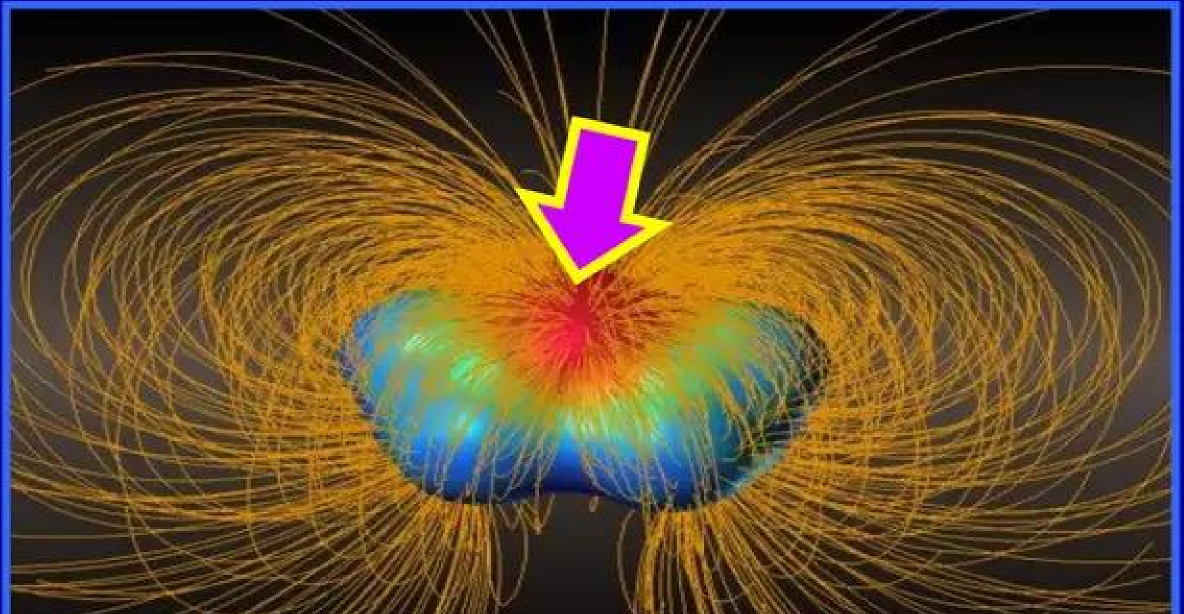
- ✓ **Born-Oppenheimer approximation is now known to break down on surfaces of carbon fullerene structures and graphene (directly observed by Bushmaker *et al*., 2009);**
- ✓ **Carbon-arc experiments of Bockris & Sundaresan and Singh *et al.* (1994) provide evidence that that LENRs and the W-L ULM carbon-seed nucleosynthetic network can occur in presence of complex mixtures of fullerenes and graphene (see Larsen 9/3/09)**
- ✓ **Born-Oppenheimer is well known to break down on metal surfaces; quoting Yale Prof. John Tully, "Breakdown of the Born-Oppenheimer assumption is the rule rather than the exception in electron transfer reactions, photochemistry, and reactions at metal surfaces." (please see his website at right)**
- ✓ **Born-Oppenheimer also known to break down in benzene rings in conjunction with quantum entanglement of protons on those rings (see Chatzidimitriou- Dreismann & Mayers, 2002). Quoting from their paper, "… our NCS results …indicate that the physical meaning of … Born-Oppenheimer [approximation] should be critically reconsidered … at least for chemical processes in the …femtosecond time scale … [we also] demonstrate that short-lived protonic quantum entanglement and decoherence are of much broader significance than realized thus far."**

→ **"Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes"**
Bushmaker *et al.*
***Nano Letters* 9 pp. 607 (2009)**

→ **See Lattice Energy LLC SlideShare presentation dated September 3, 2009, at:**
http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

→ **See Prof. Tully's Yale website at:**
http://www.chem.yale.edu/~tully/research.html

→ **"Sub-femtosecond dynamics and dissociation of C-H bonds in solid polystyrene and liquid benzene"**
C. Chatzidimitriou-Dreismann & Mayers
***Journal of Chemical Physics* 116 pp. 1617-1623 (2002)**



E-M field lines surrounding a benzene ring

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Many-body collective Q-M effects are widespread in Nature

Collective many-body effects and quantum entanglement work together

- ✓ Many-body collective oscillations and mutual quantum entanglement of protons (as well as deuterons and tritons) and electrons (e.g., SPs on metallic hydride surfaces), in conjunction with a breakdown of the Born-Oppenheimer approximation, appear to be relatively common in nature, occurring in many different types of physical systems

- ✓ While these many-body collective processes chronicled by Chatzidimitriou-Dreismann *et al.* operate very rapidly and nanoscale coherence can only persist for time spans on the order of femtoseconds (10^{-15} sec) to attoseconds (10^{-18} sec), nuclear processes such as weak interaction ULM neutron production and neutron capture operate on even faster time-scales, i.e., 10^{-19} to 10^{-22} sec. Therefore, LENRs as explained by the Widom-Larsen theory can easily take advantage of such many-body collective quantum effects as an integral part of their amazing dynamical repertoire

- ✓ It is well-known that metallic surface nanostructures and SP electrons can have configurations that are able to effectively absorb E-M energy over a wide area, transfer and concentrate it, and in conjunction with contiguous surface patches of collectively oscillating protons, create nuclear-strength local electric fields. According to W-L theory of LENRs, electroweak neutron production can then follow

→ C. Chatzidimitriou-Dreismann (Technical University of Berlin) and his collaborators have published extensively on collective proton dynamics since 1995. Please also see:

*“*Attosecond quantum entanglement in neutron Compton scattering from water in the keV range” (2007); can be found at

http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

“Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 - 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces.”

→ Also: *“*Entangled mechanical oscillators,*”* J. Jost *et al.*, *Nature* 459 pp. 683 - 685 4 (2009) in which, “... mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way.”

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Many-body collective Q-M effects are widespread in Nature

Mutual entanglement of protons and electrons observed experimentally

Phenomenon is well-established; measured experimentally:

- ✓ **Protons found within a wide variety of many-body molecular systems spontaneously oscillate coherently/collectively; their quantum mechanical (QM) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons; amazingly, this behavior occurs even in comparatively smaller, simpler molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexaclorometallate (see Krzystyniak *et al*., 2007 and Abdul-Redah & Dreismann, 2006). Quoting from the paper by Krzystyniak *et al*., "… different behaviors of the observed anomaly were found for LaH_2 and LaH_3 … As recognized by Chatzidimitriou-Dreismann *et al.* Coulombic interaction between electrons and protons may build up entanglement between electrons and protons. Such many body entangled states are subject to decoherence mechanisms due to the interaction of the relevant scattering systems with its environment … one can conclude that the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of the [attached] heavier nuclei."**

- ✓ **Elaborating further from Chatzidimitriou-Dreismann (2005), "Further NCS experiments confirmed the existence of this effect in quite different condensed matter systems, e.g., urea dissolved in D_2O, metallic hydrides, polymers, 'soft' condensed matter, liquid benzene, and even in liquid H_2-D_2 and HD."**

→ **"Anomalous neutron Compton scattering cross sections in ammonium hexachlorometallates," Krzystyniak *et al.*, *Journal of Chemical Physics* 126 pp. 124501 (2007)**

→ **"Irreversible hydrogen quantum dynamics and anomalous scattering behavior in liquids and solids," Abdul-Redah & Chatzidimitriou-Dreismann, *International Journal of Hydrogen Energy* 31 pp. 269 - 276 (2006)**

→ **"Attosecond protonic quantum entanglement in collision experiments with neutrons and electrons," C. Chatzidimitriou-Dreismann, *Laser Physics* 15 pp. 780 - 788 (2005)**

→ **Please also see book chapter by Chatzidimitriou-Dreismann *et al.*, "Attosecond effects in scattering of neutrons and electrons from protons", in *Decoherence, Entanglement, and Information Protection in Complex Quantum Systems,* Akulin *et al.* eds., NATO Science Series II Vol. 189 Springer Netherlands (2005)**

With regard to the dynamics and orientation of benzene molecules and polycyclic aromatic hydrocarbons as they are adsorbed on a metallic catalyst's surface please see:

→ **"Aromatic adsorption on metals via first-principles density functional theory," S. Jenkins, *Proceedings of the Royal Society* 465 pp. 2949 - 2976 (2009); quoting from it, "[Benzene] adopts a flat-lying … geometry, binding to the surface through donation of electrons through one or both of its degenerate HOMOs and back-donation into one or both of its two degenerate LUMOs."**

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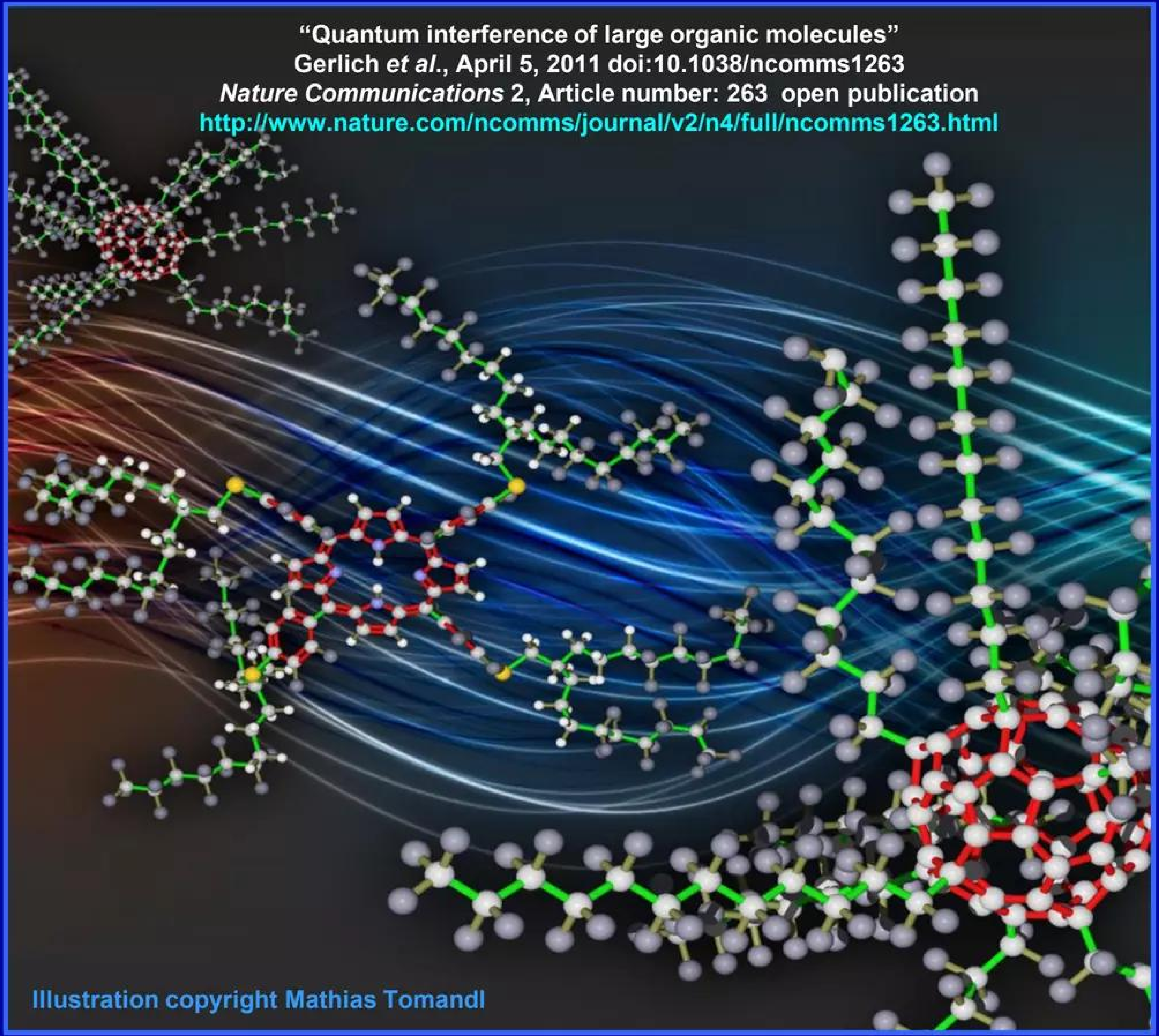
Many-body collective Q-M effects are widespread in Nature

Quantum entanglement and delocalization in molecular ensembles

"PFNS10 and TPPF152 contain 430 atoms covalently bound in one single particle. This is ~350% more than that in all previous experiments and it compares well with the number of atoms in small Bose–Einstein condensates (BEC), which, of course, operate in a vastly different parameter regime: The molecular de Broglie wavelength λ_{dB} is about six orders of magnitude smaller than that of ultracold atoms and the internal molecular temperature exceeds typical BEC values (T<1 μK) by about nine orders of magnitude. Although matter wave interference of BECs relies on the de Broglie wavelength of the individual atoms, our massive molecules always appear as single entities."

"Quantum interference of large organic molecules"
Gerlich *et al*., April 5, 2011 doi:10.1038/ncomms1263
Nature Communications 2, Article number: 263 open publication
http://www.nature.com/ncomms/journal/v2/n4/full/ncomms1263.html



Artistic view of most complex and massive molecules (PFNS-10, TPP-152) brought to quantum interference by Gerlich *et al.* (2011)

"Our experiments prove the quantum wave nature and delocalization of compounds composed of up to 430 atoms, with a maximal size of up to 60 Å, masses up to *m*=6,910 AMU and de Broglie wavelengths down to $\lambda_{dB}=h/mv\simeq 1$ pm ... In conclusion, our experiments reveal the quantum wave nature of tailor-made organic molecules in an unprecedented mass and size domain. They open a new window for quantum experiments with nanoparticles in a complexity class comparable to that of small proteins, and they demonstrate that it is feasible to create and maintain high quantum coherence with initially thermal systems consisting of more than 1,000 internal degrees of freedom."

Lattice Energy LLC

Many-body collective Q-M effects are widespread in Nature

Quantum entanglement and delocalization in molecular ensembles

"Another biological process where entanglement may operate is photosynthesis, the process whereby plants convert sunlight into chemical energy. Incident light ejects electrons inside plant cells, and these electrons all need to find their way to the same place: the chemical reaction center where they can deposit their energy and sett off reactions that fuel plant cells. Classical physics fails to explain the near-perfect efficiency with which they do so."

"... In a quantum world, a particle does not just have to take one path at a time; it can take all of them simultaneously. The electromagnetic fields within plant cells can cause some of these paths to cancel one another and others to reinforce mutually, thereby reducing the chance the electron will take a wasteful detour and increasing the chance it will be steered straight to the reaction center."

"The entanglement would last only a fraction of a second and would involve molecules that have no more than about 100,000 atoms. Do any instances of larger and more persistent entanglement exist in nature? We do not know, but the question is exciting enough to stimulate and emerging discipline: quantum biology."

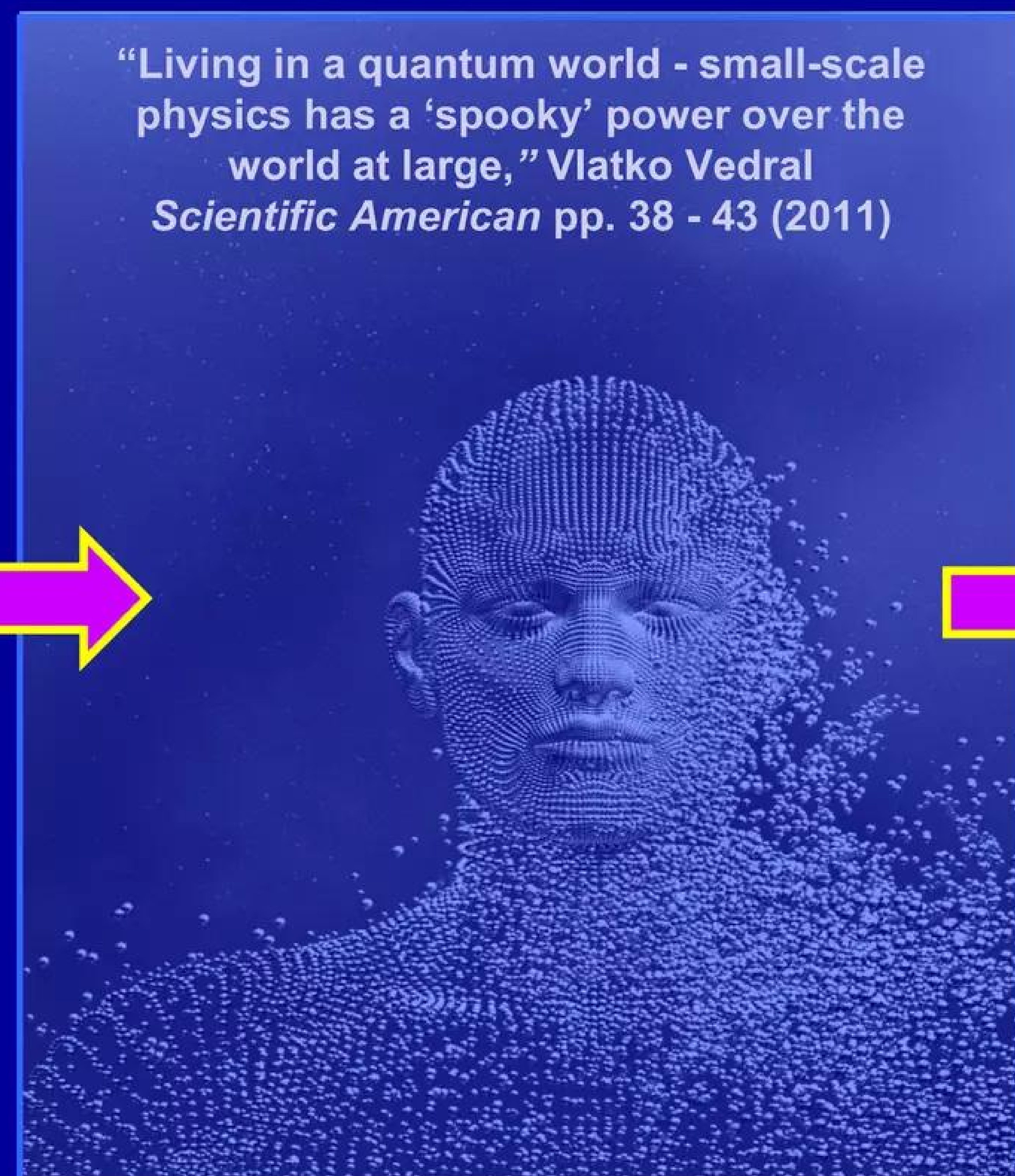
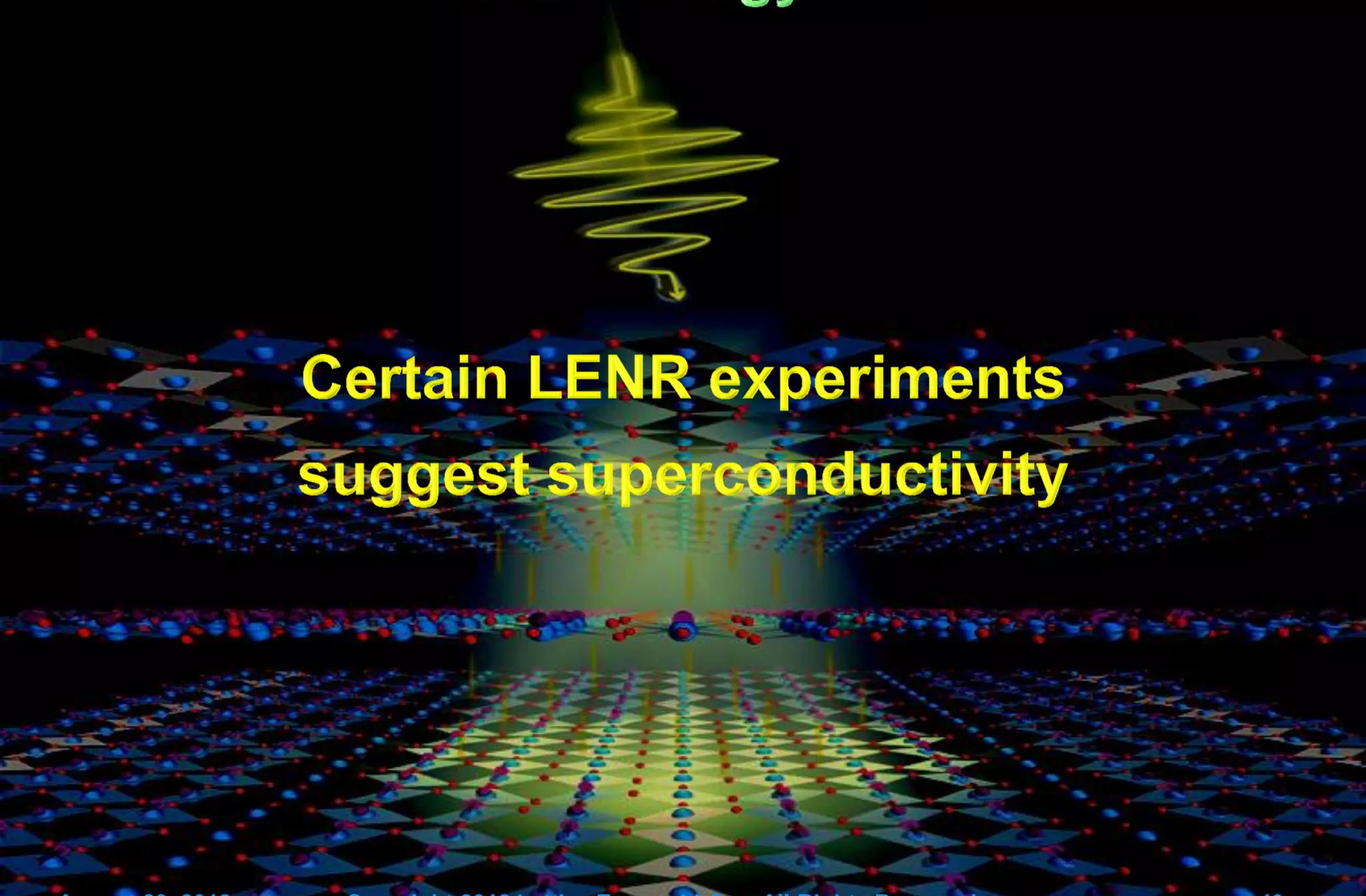


Image credit : Kenn Brown, Mondolithic Studios
Cover of *Scientific American* June 2011

"Not only is the universe stranger than we imagine, it is stranger than we *can* imagine."

Often misattributed to Sir Arthur Eddington; more likely adapted from J.B.S. Haldane (1927)



Certain LENR experiments suggest superconductivity

Lattice Energy LLC

Miley *et al.* conference presentation at ICONE-8571 (2000)

Ultrathin Pd-wire experiments show anomalous resistance fluctuations

G. Miley, G. Selvaggi, A. Tate, M. Okuniewski, M. Williams, and D. Chicea [not online]

Quoting directly from report: Basic Spiral Wire Electrode Loading/Reaction Experiments:

"In support of the slide electrode studies, a basic hydrogen isotope loading experiment was carried out using a 50-*μm* diameter Pd wire, 1-m long, as the cathode. As shown in Fig. 4, this wire was spiraled around a Teflon support to form the cathode for the loading/reaction experiment. The selection of a very long wire length was based on theoretical considerations concerned with enhancing electromigration effects, hence maximizing the loading (Celani *et al.* 1998). A thicker platinum wire, formed in concentric spiral configuration around the support, served as the anode. The 50-*μm* wire cathode is too thin to be visible in Fig. 4, but the thicker platinum anode wire can just be seen."

"This unusual spiral wire configuration provides electrode-loading properties similar to the thin-film, but as noted earlier, allows for easier diagnostics of the loading dynamics. This wire was carefully pre-conditioned by pre-stressing and annealing it to provide a reconstruction of the crystalline structure. In addition to the cell with the 'active' Pd wire, an identical second cell with a non-reacting platinum wire cathode was instructed to provide reference calorimetric data. Both cells used the same power supply with an applied voltage of ~5 V and current of 5-50 mA. The electrolyte was $CaSO_4$ in D_2O with a 10^{-5} M/l concentration. Integrated circuit temperature transducers were used for the calorimetric measurements. Electronic slope with offset trimming was employed to drive these devices. The various data channels were connected through a multiplexer switch unit, allowing real-time on-line data acquisition on a dedicated computer. The circuitry also provided super-position of AC current on top of the steady-state DC current to provide continuous monitoring of the potential along the wire to infer its electrical resistivity during the run. As illustrated in Fig. 5, the resistivity has in turn, been shown to be directly correlated with the deuterium loading in palladium (the curves shown are for a flat-plate geometry, but since resistivity ratios are involved, they are thought to be reasonably accurate for the present wire experiment)."

Fig. 5. Resistivity of Palladium vs. Atomic Loading Ratio of Deuterium (blue curve) and Hydrogen (red curve) in Pd (McKubre, 1992).

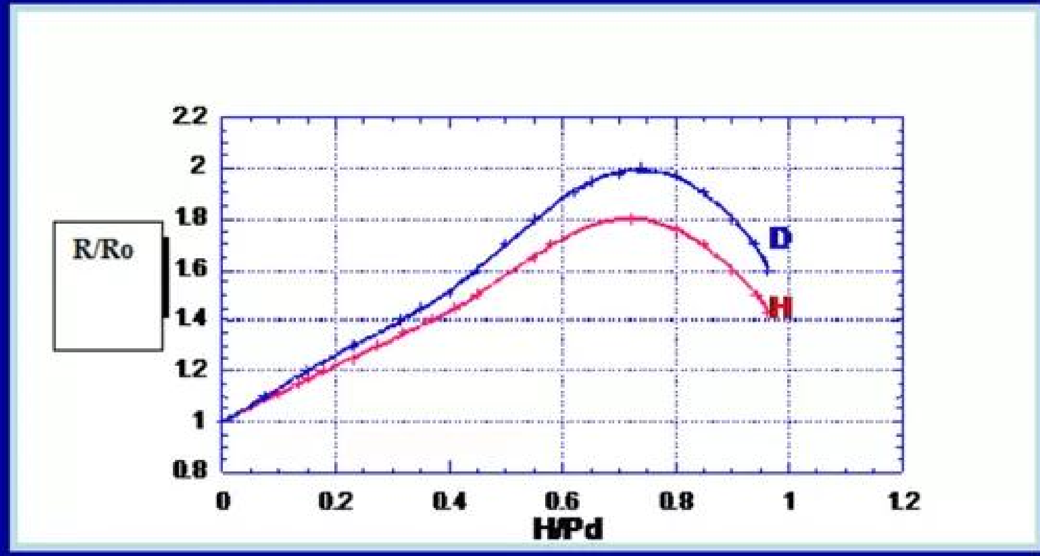
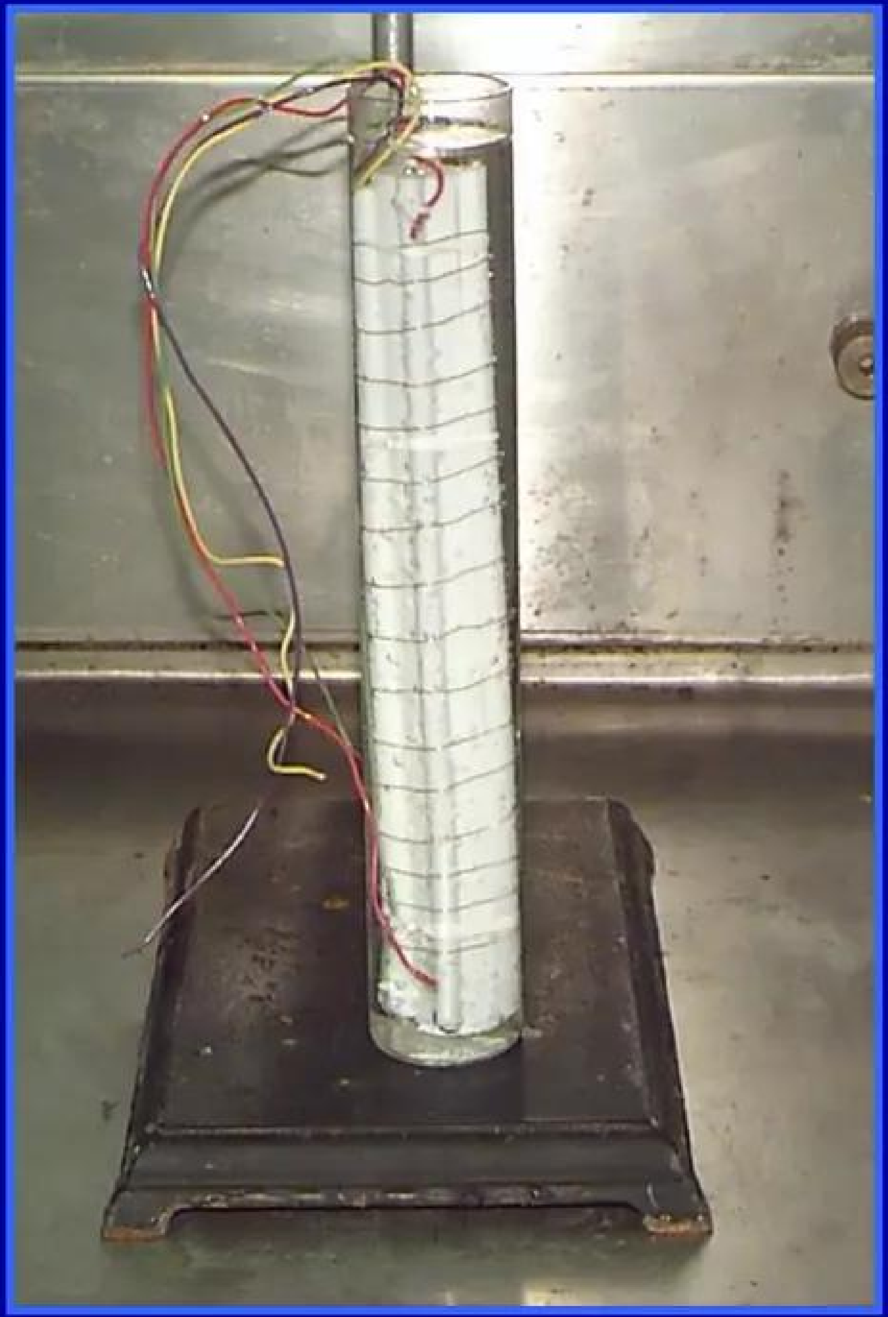


Fig. 4. Photo of the spiral wire loading experiment.



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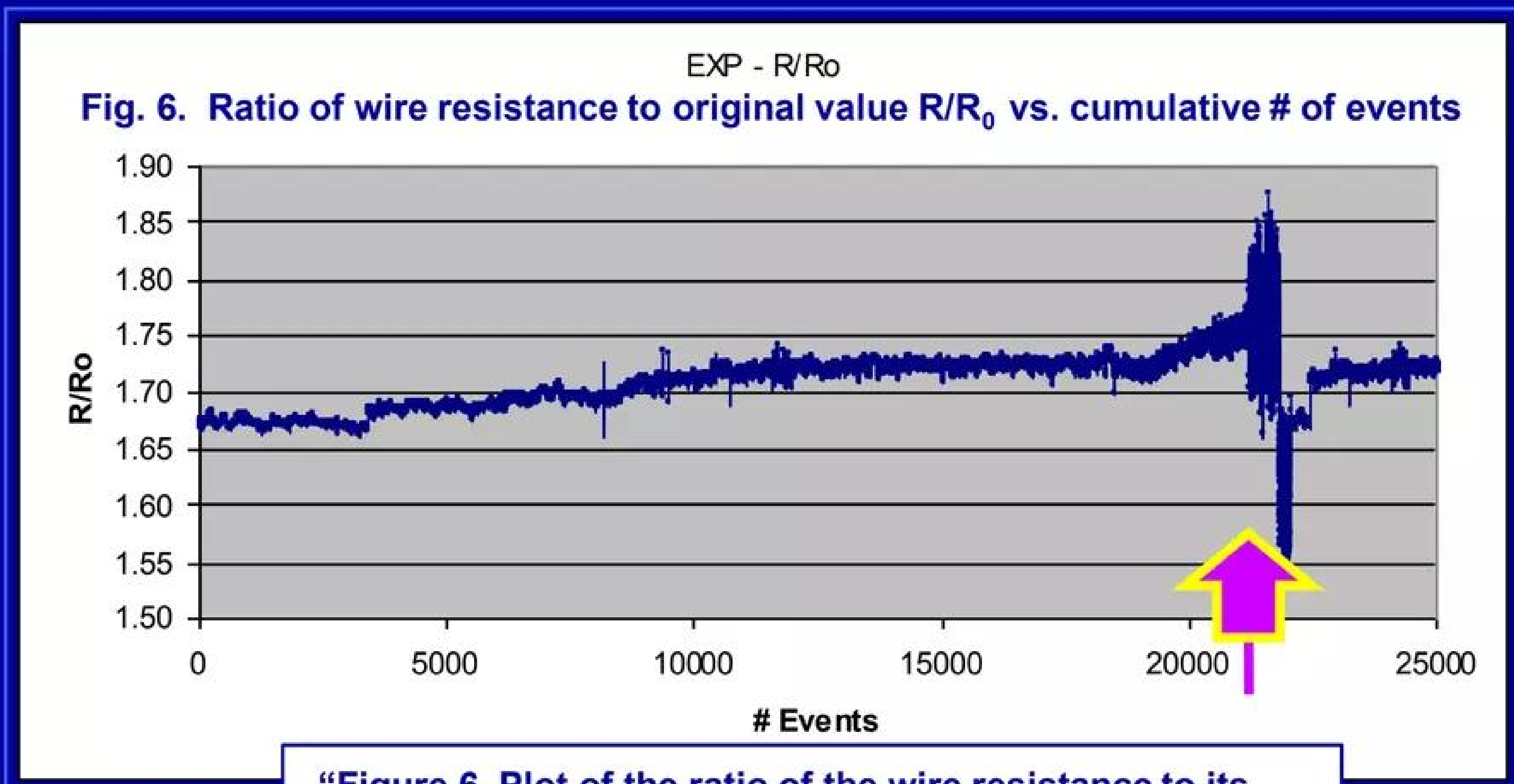
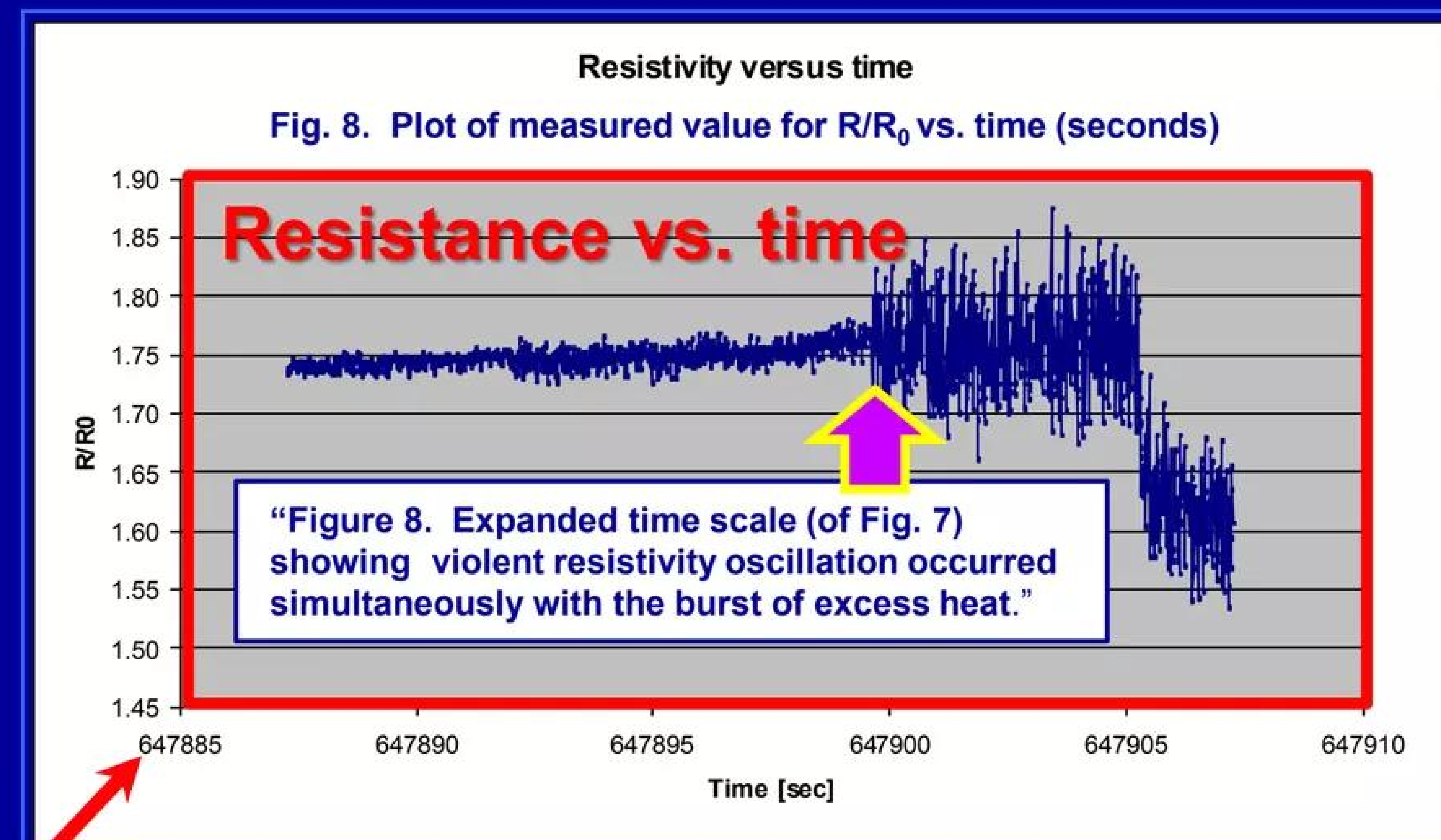
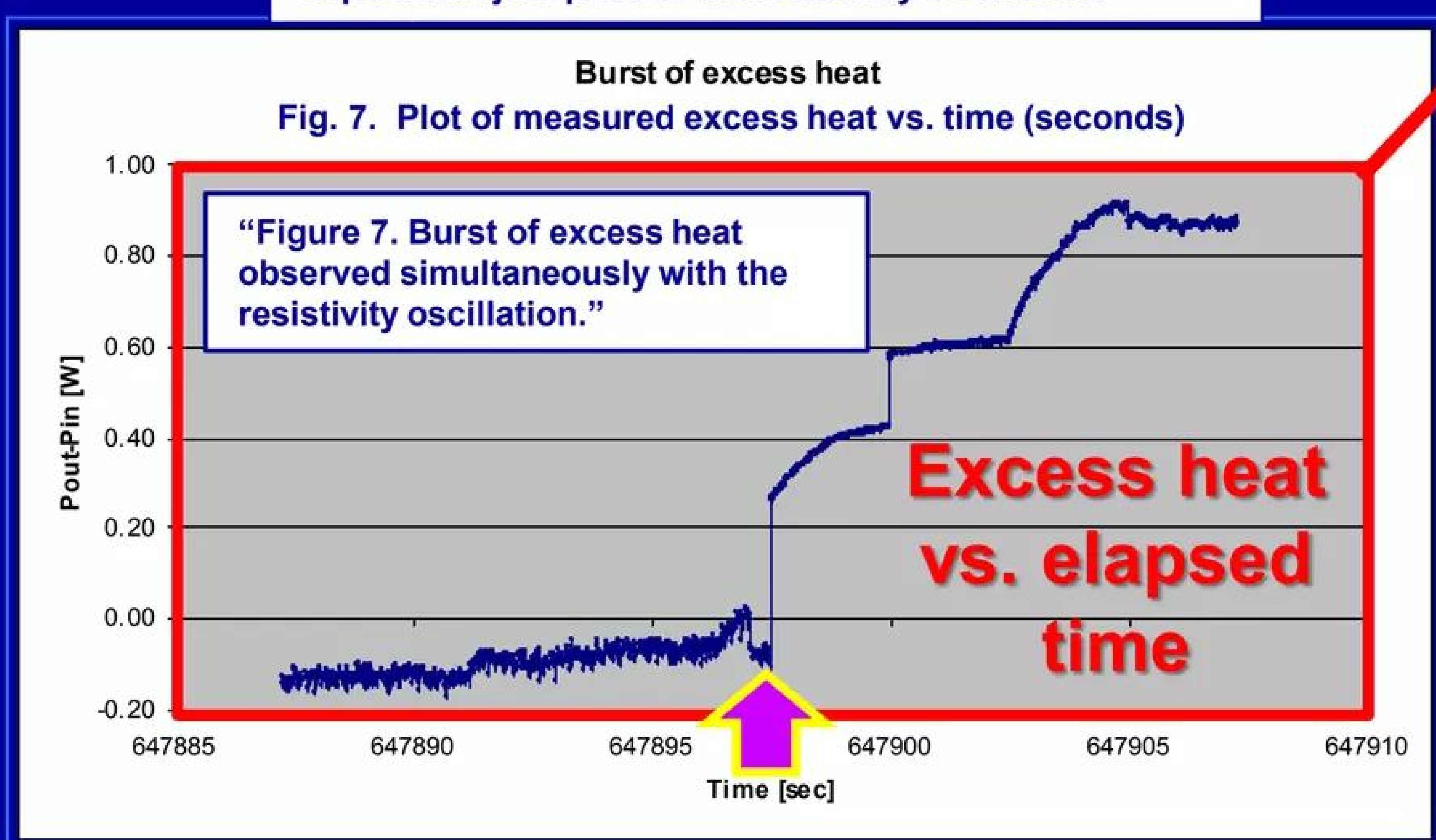
Miley *et al.* conference presentation at ICONE-8571 (2000)

Figures show correlation of wire resistance fluctuations with heat burst



"Figure 6. Plot of the ratio of the wire resistance to its initial value, R/Ro over 25000 data points. The time period shown corresponds to three weeks of the experiment just prior to the resistivity oscillation."





"The loading process was carefully controlled so that the build-up rate was low; hence, surface stresses in the wire were minimized, allowing time for natural annealing to occur so as to prevent micro cracking or an 'over' concentration of D on the cathode. This step continued over almost three weeks with gradual increases in the electrolytic current each day. The change in resistance of the wire was measured continuously during the loading process in order to determine the loading ratio (D/Pd atom). The measured resistivity (Fig. 6), R/Ro (Ro = initial resistivity), increased up to 1.87, then reversed its slope drastically dropping down to 1.54. Thus, as seen from the loading curve for D in Fig. 5, this behavior indicates the loading passed through 0.75 atoms D/Pd at the maximum resistivity and then continued to a loading of 0.97-0.98 atom D/Pd. At that point, as shown in Fig. 6, the resistance suddenly underwent a violent oscillation and then dropped to a slightly lower steady-state value. "

"As seen from Figs. 7 and 8, the resistivity oscillations were accompanied by a sudden burst of high excess power ('excess' power is defined as the difference between the power output and the power input). Following this initial burst, an 'excess' power of ~1 W (with an input power of ~ 0.3 W) was obtained for a few minutes before damage to the cell wiring forced shutdown of the run."

Lattice Energy LLC

Miley *et al.* conference presentation at ICONE-8571 (2000)

Good correlation of large wire resistance fluctuations with heat burst

Continuing to quote from ICONE conference report:

- ✓ "These results are very distinctive and are well out of the uncertainty limits associated with the resistivity and power measurements. An error of ± 0.1 is associated with each point in the *R/Ro* measurement based on a random resistivity measurement error of 2 Ohms. A power measurement of ± 45 mW is inferred from an error propagation analysis of temperature measurements."
- ✓ "This wire experiment clearly demonstrates the importance of obtaining a very high deuterium (or proton) loading in order to study the 'excess power' phenomena. This point has been widely cited by other workers in the field for some time (Celani *et al.* 1999). However, prior to the development of the unique spiral wire and thin-film electrodes, it had not been possible to reproducibly achieve such high loadings. Not only is the electrode configuration important, but also as noted earlier, pre-conditioning and controlled loading techniques are equally important factors."
- ✓ "As already noted, prior wire loading experiments at INFN Frascati originally discovered the oscillating resistivity phenomena at ultra-high loadings. However, the present results are the first to establish the simultaneous evolution of excess heat. This discovery is very fundamental to understanding the dynamical resistivity and heating plus potential nuclear reactions in highly loaded metals."

Lattice comments:

- ✓ This series of interesting thin Pd wire experiments was designed and conducted by Giovanna Selvaggi, who came to UIUC to study in Prof. George Miley's lab at the suggestion of Dr. Vittorio Violante (ENEA, Frascati, Italy)
- ✓ Ms. Selvaggi initially learned how to conduct such experiments in Violante's laboratory in Frascati; conducting ultrathin wire experiments had been popular amongst a small subgroup of Italian LENR researchers, e.g., Dr. Francesco Celani *et al*., dating back to the mid-1990s
- ✓ Italian LENR researchers had previously reported large fluctuations of resistance in such experiments (e.g., Celani *et al*. 1995-96); however, this ICONE paper reports the results of experiments conducted at UIUC that were the first-ever to unambiguously correlate such extreme oscillations in the resistivity of a thin-wire Pd electrode with the onset of a burst of excess cathodic heat measured via calorimetry
- ✓ Intriguing possibility: at macroscopic level, Selvaggi's thin-wire Pd cathodes were *ca*. room temperature (STP ~273^{o} K) or above when extreme resistance fluctuations occurred. If those disturbances were truly caused by evanescent μ-scale superconducting regions that were appearing and disappearing in/on Pd cathode, then maybe some form of ~room temperature superconductivity thereon is a possibility

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Patent description:

"HIGH T_c PALLADIUM HYDRIDE SUPERCONDUCTOR"
US #7,033,568 B2
Inventor and Assignee: Paolo Tripodi, Rome, Italy
Originally filed: March 12, 2001
USPTO issued: April 25, 2006
Copy of issued patent available at: http://ip.com/patfam/xx/22693758

Abstract (quoting from very first page of issued US patent):

"A palladium hydride superconductor, PdyHx where yHx is 1Hx, 2Hx, or 3Hx, having a critical temperature Tc ≧ 11 K and stoichiometric ratio x ≧ 1. The critical temperature is proportional to a power of the stoichiometric ratio, which is stable over periods exceeding 24 hours, temperature variations from 4 K to 400 K, and pressures down to 1 mbar. The palladium hydride is coated with a stabilizing material such as a metal, metal oxide, ceramic, or polymer that can bond to palladium. It can be made by electrochemically loading a palladium lattice with isotopic hydrogen in an electrolytic solution, by allowing isotopic hydrogen to diffuse into a palladium thin film in a pressure chamber, or by injecting isotopic hydrogen into a palladium thin film in a vacuum chamber. The stabilizing material can be electrochemically bonded to the surface of the palladium hydride, or deposited using chemical vapor deposition or molecular beam epitaxy."

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Related paper:

"Possibility of high temperature superconducting phases in PdH"
P. Tripodi, D. Gioacchino, R. Borelli, and J. Vinko
Physica C. Superconductivity 388 - 389 pp. 571- 572 (2003)
http://144.206.159.178/ft/844/87512/1485936.pdf

Abstract:

"Possible new superconducting phases with a high critical transition temperature (T_c) have been found in stable palladium-hydrogen (PdH_x) samples for stoichiometric ratio x = H/Pd ≥ 1, in addition to the well-known low critical transition temperature ($0 \leq T_c \leq 9$) when x is in the range ($0.75 \leq x \leq 1.00$). Possible new measured superconducting phases with critical temperature in the range $51 \leq T_c \leq 295$ K occur. This T_c varies considerably with every milli part of x when x exceeds unit. A superconducting critical current density $J_c \geq 6.1 \times 10^4 A\ cm^{-2}$ has been measured at 77 K with H_{DC} = 0 T."

Related paper:

"Superconductivity in PdH: phenomenological expl*anation*"
P. Tripodi, D. Gioacchino, and J. Vinko
Physica C. Superconductivity 408 - 410 pp. 350 - 352 (2004)
http://www.sciencedirect.com/science/article/pii/S0921453404002746

Abstract:

"Experimental data on PdH_x(D) at 300 K shows electrical resistivity *ρ* lower than that of the pure Pd for stoichiometry x = H/Pd close to the unit. At this stoichiometric value x = 1 a T_c of 9 K and higher T_c for x > 1 have been measured. In these systems T_c increases with stoichiometry x, hence a phenomenological description of the *ρ* for highly loaded PdH(D) system at 300 K has been developed. This approach uses a parallel model of two concurrent electrical transport processes: (i) *ρ* has a linear raise with the x, due to the increase of Pd lattice relative volume, (ii) ρ has an exponential decrease versus x due to superconducting fluctuations at very high x in PdH(D). Under the assumption of our model, PdH_x could be considered as a possible room temperature superconductor. Inverse isotopic effect for 0.6 > x > 0.96 changes to normal isotopic effect at stoichiometry x_ψ>1."

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpts (from Column 5 Lines 10 - 16 and Column 6 Lines 39 - 67 in 2006 US patent #7,033,568 B2):

- ✓ **"As previously mentioned, palladium hydride systems $Pd^{y}H_x$ for average stoichiometric ratios $x \leqq 1$ are known in the art. However, the palladium hydride system becomes intrinsically unstable for stoichiometric ratios approaching an average stoichiometric ratio $x \sim 1$. As a result, little is known about the properties of such systems for average stoichiometric ratios $x \geqq 1$."**

- ✓ **"It should be noted that the relative resistance measurement technique can only measure the average stoichiometric loading ratio x in palladium cathode (203) because the dissolution of ^{y}H in palladium cathode (203) does not uniformly occur throughout the cathode. In particular, since dissolution of ^{y}H in palladium cathode (203) primarily occurs along the outer surface of the cathode, the distribution of ^{y}H throughout palladium cathode (203) is expected to have a radial dependence and to be much larger along the outer layer of cathode (203) than along its core. However, neither the homogeneity nor the gradient of the loaded ^{y}H atoms inside palladium cathode (203) can be known from the average measured stoichiometric loading ratio x."**

- ✓ **"The resistance across palladium cathode (203) can be measured in any number of ways known in the art. In one embodiment, shown in FIG. 2, the resistance is measured by generating an AC signal with an AC signal generator (206), passing the generated signal through palladium cathode (203), and measuring the voltage drop in the signal across the cathode. Prior to measuring the voltage drop across cathode (203), the DC bias added to the generated AC signal by the current produced in electrochemical cell (201) is filtered out through high-pass filters (207). Using this technique, the relative resistance of palladium cathode (203) can be determined from measurements of its resistance before power supply (205) is turned on and at some subsequent time during the loading process after an amount of ^{y}H has been loaded onto palladium cathode (203) to achieve a stoichiometric loading ratio x."**

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

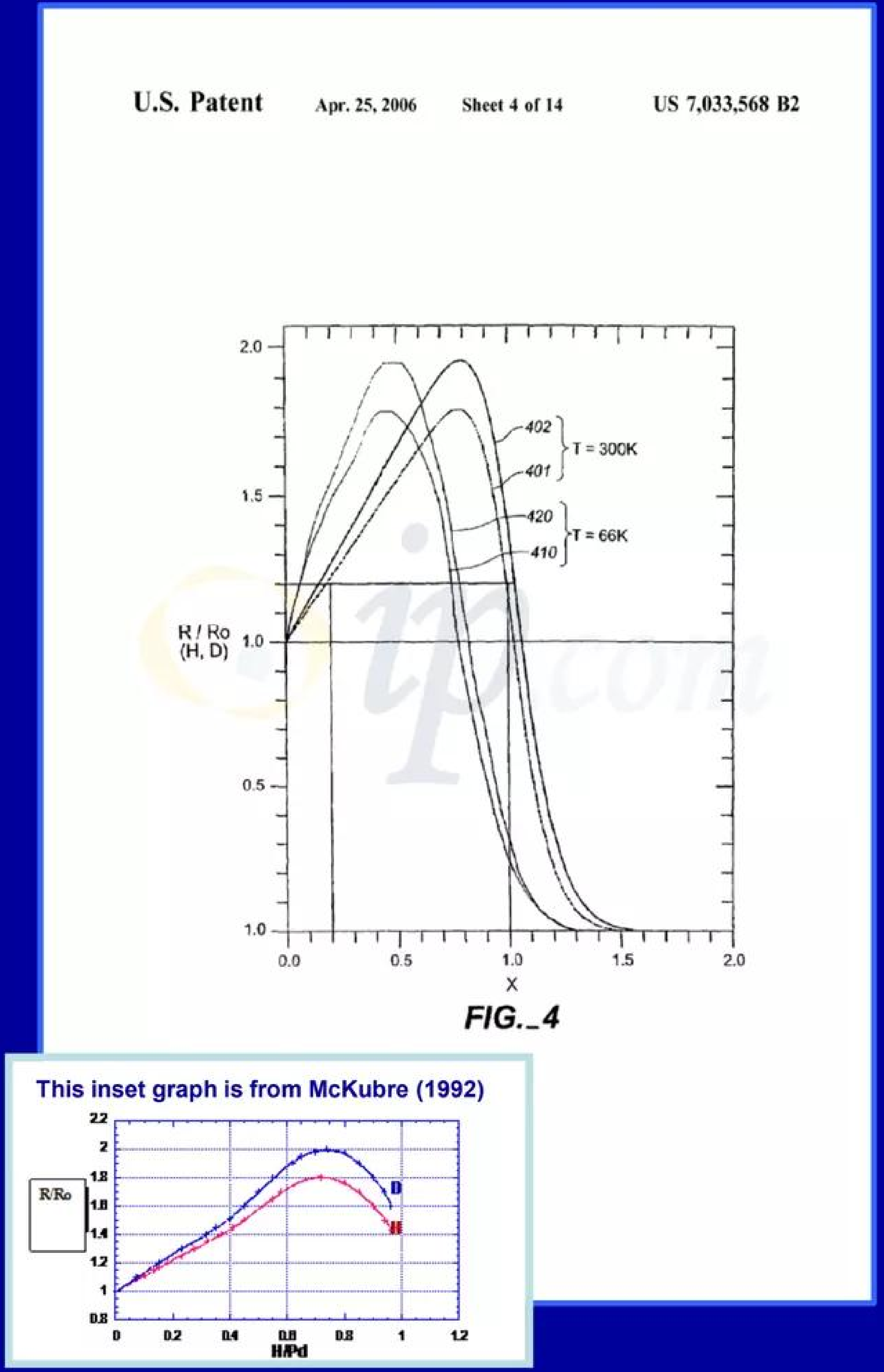
Excerpts (from Column 7 Lines 1 - 36 in US patent):

- ✓ "Referring again to FIG. 3, the relative resistances of ${}^yH$ loaded Pd lattice systems at room temperature are known for systems having average stoichiometric loading ratios x ≦ 1. However, no relative resistances are known for Pd^yH_x systems having average stoichiometric loading ratios of x > 1 because of the inherent instability of such systems which rapidly and spontaneously undergo ${}^yH$ deloading. Consequently, to measure the stoichiometric loading ratio for Pd^yH_x systems having an average stoichiometric loading ratio x > 1 using a relative resistance measurement technique, a model for the relative resistance as a function of stoichiometric loading ratio must be developed so that the relative resistance measurements for x ≦ 1 can be extrapolated to the region 1 ≦ x ≦ 3."

- ✓ "As shown in FIG. 4, a phenomenological model has been developed. The model predicts the relative resistance of Pd^yH_x systems at room temperature will exponentially decrease with increasing stoichiometric loading ratio for average stoichiometric loading ratios x > 1. Moreover, the model predicts the relative resistance will decrease to essentially 0 resistance at an average stoichiometric loading ratio of x ≧ 1.6, such that the Pd^yH_x system will be in a room temperature superconducting state at such loading ratios."

- ✓ "The details of the phenomenological model are as follows. The palladium hydride system Pd^yH_x is modeled as having two electron transport mechanisms available in parallel, one superconducting and the other normal or non-superconducting. Each electron transport mechanism is modeled to provide a unique conductive pathway for electrons in the Pd^yH_x system, such that each unique conductive pathway has a corresponding resistance that uniquely varies with the stoichiometric loading ratio x of the system. Because the two conductive pathways are modeled to be present in parallel, their corresponding resistances are added in parallel to obtain the overall resistance of the Pd^yH_x system."

Figure 4 (extracted directly from issued US patent):



This inset graph is from McKubre (1992)

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpts (from Column 8 Lines 1 - 44 in US patent):

- ✓ **"Adding the relative resistances from Eq. 1 and Eq. 2 in parallel, one obtains a phenomenological expression for the relative resistance of the $Pd^{y}H_{x}$ at room temperature as a function of the stoichiometric loading ratio of ^{y}H to Pd in the system. The expression can be written as:**

  $R/R_0 = (1 + \lambda$ [illegible] $^{-\gamma(x-xc)/k_B}$ [illegible] $/1+$ [illegible] $+ \beta$ [illegible] $^{-\gamma(x-xc)/k_B}$ [illegible] **(Eq. 3)**

  where R, R_0, λ, β, γ, x, x_c, k_B and T are as defined in Eq. 1 and Eq. 2. The expression in Eq. 3 was fit to experimental data for the relative resistance R/R_0 at stoichiometric loading ratios $x \leqq 1$ to determine the free parameters λ, β, γ and x_c."

- ✓ **"Using the fitted free parameters, the resulting curve of the relative resistance of a $Pd^{y}H_{x}$ system as a function of stoichiometric loading ratio up to a maximum loading ratio of x = 2 is shown in FIG. 4 for a temperature T of 300 K, and for ^{1}H (401) and ^{2}H (402). As can be seen from FIG. 4, at 300 K the $Pd^{y}H_{x}$ system is predicted to be a superconductor at stoichiometric loading ratios greater than a critical stoichiometric loading ratio $x_c \geqq 1.6$. At different temperatures, the phenomenological relative resistance curves plotted in FIG. 4 are compressed so that the critical stoichiometric loading ratio decreases with decreasing temperature. For example, FIG. 4 also shows the relative resistance of a $Pd^{y}H_{x}$ system as a function of stoichiometric loading ratio for ^{1}H (410) and ^{2}H (420) at a temperature of 66 K. In these curves, the system is seen to be a superconductor at critical stoichiometric loading ratio $x_c \geqq 1.2$."**

- ✓ **"Referring back to FIG. 2, ^{y}H loading of palladium cathode (203) by electrochemical cell (201) can be performed until the relative resistance measurement of the cathode (203), as measured by the AC signal produced by AC signal generator (206), indicates from the plot of FIG. 4 that the palladium cathode (203) has been loaded with sufficient ^{y}H to yield an average ^{y}H to Pd stoichiometric ratio of $x \geqq 1$. Thus the ^{y}H loading of palladium cathode (203) can be performed until the relative resistance of the cathode rises to its maximum of ~1.8, then descends to negative relative resistance values indicating an average stoichiometric loading ratio of $x \geqq 1$ as shown in FIG. 4."**

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpt (from Column 9 Lines 28 - 45 in US patent):

- ✓ "As shown in FIG. 4, the stable relative resistance of 1.2 at region (503) can result from either a ^{y}H to Pd stoichiometric ratio of 0.2 or 0.98. The stoichiometric ratio is known to be 0.98 because of the regions of dramatic rise (504) and subsequent decay (505) of the relative resistance that occur when the palladium cathode (203) finally deloads. The region of dramatic rise (504) corresponds to the stoichiometric ratio region between 0.7 ≦ x ≦ 0.98 during which the relative resistance increases with decreasing stoichiometric ratio. The region of subsequent decay (505) corresponds to the stoichiometric ratio region between 0.0 ≦ x ≦ 0.7 during which the relative resistance decreases with decreasing stoichiometric ratio and returns to unity at a stoichiometric ratio of x=0. Referring again to FIG. 5, the region (503) of stable relative resistance 1.2 of the ^{y}H loaded palladium cathode (203) at a stoichiometric ratio of x = 0.98 is seen to last for a period of approximately 12000 seconds or 3.3 hours before deloading occurs."

U.S. Patent Apr. 25, 2006 Sheet 4 of 14 US 7,033,568 B2

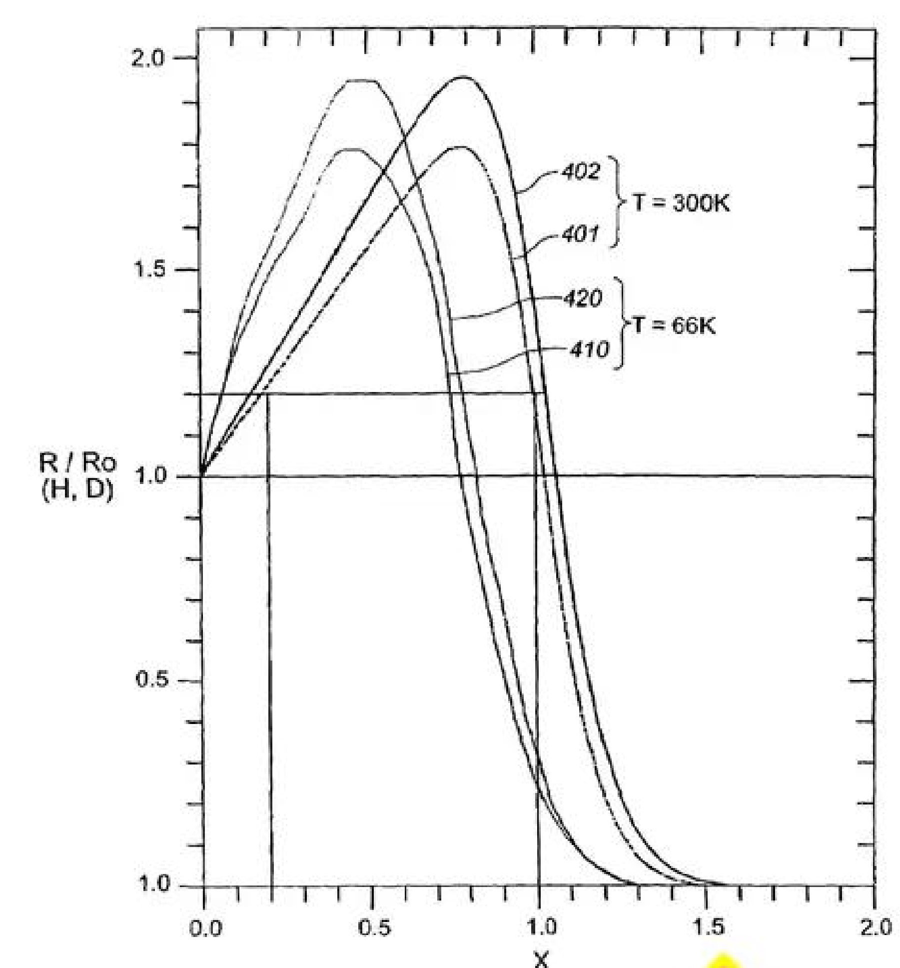


FIG._4

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Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpts (from Column 11 Lines 51 - 67 and Column 12 Lines 1 - 24 in US patent):

- ✓ **"Using this relationship, the length of the domain of the Pd^yH_x sample (203) undergoing a superconducting phase transition at a critical temperature of 51.6 K as shown in FIG. 6 is estimated to be around 1 mm."**

- ✓ **"Referring again to FIG. 6, the second interesting property seen in the figure is that the phase transition in the electrical resistance seen in plot 601 at 51.6 K disappears when a 1 T external magnetic field is applied as seen in plot 602. This suggests that the superconducting phase in the domain having a superconducting phase transition at 51.6 K has been destroyed by the applied magnetic field according to the well known Meissner effect. In the Meissner effect, the critical temperature of a superconducting phase transition is a function of an externally applied magnetic field, H. As shown in FIG. 8, the critical temperature of a superconducting phase is a maximum in the absence of an external magnetic field, and decreases with increasing magnetic field up to a critical field $H_c(0)$ at which the critical temperature reaches 0K, and the superconducting phase is completely destroyed."**

- ✓ **"Thus, the sample domain in plot 601 of FIG. 6 having a critical temperature $T_{c3}(0)$ = 51.6K could be associated with a superconducting phase having a critical field $H_{c3}(0)$ < 1T as shown in FIG. 8. Consequently, the superconducting phase in that domain is destroyed when the 1 T magnetic field is applied to the sample as shown in plot 602. The domain having a critical temperature $T_{c1}(1)$ = 31.3 K in plot 602 of FIG. 6, could be associated with a superconducting phase having a critical temperature $T_{c1}(0)$ > 55 K, and a critical field $H_{c3}(0)$ > 1 T as shown in FIG. 8. Consequently, the superconducting phase of the domain is not destroyed when the 1 T magnetic field is applied to the sample, although the critical temperature is lowered to a value $T_{c1}(1)$ = 31.3 K as shown in plot 602. Similarly, the domain having a critical temperature $T_{c2}(1)$ = 18.8 K in plot 602, could also be associated with a superconducting phase having a critical temperature $T_{c2}(0)$ > 55 K, and a critical field $H_{c2}(0)$ > 1 T, so that the superconducting phase of the domain is not destroyed when the 1 T magnetic field is applied to the sample, although the critical temperature is lowered to a value $T_{c2}(1)$ = 18.8 K as shown in plot 602."**

Lattice Energy LLC

Tripodi patent was first filed in 2001 and issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpts (from Column 13 Lines 12 - 31 in US patent):

- ✓ "As shown in FIG. 10B, another sample had an electrical resistance curve (1002) with a phase transition at 82 K that is indicative of a multi-domain sample having a superconducting domain with a critical temperature of 82 K. The electrical resistance curve of this sample was measured again 24 hours later, and resulted in curve (1020) which shows the persistence of the superconducting domain with the critical temperature of 82 K for a period of at least 24 hours. The absolute resistance of curve (1020) is somewhat higher than the absolute resistance of curve (1002) because some of the hydrogen isotopes have been able to escape from the sample, thereby increasing its absolute resistance as shown in FIG. 4."

- ✓ "Still other samples were produced with superconducting domains at even higher critical temperatures. FIG. 11A shows the electrical resistance measurements of a sample having a phase transition at 90 K that is indicative of a multi-domain sample having a superconducting domain with a critical temperature of 90 K."

U.S. Patent Apr. 25, 2006 Sheet 11 of 14 US 7,033,568 B2

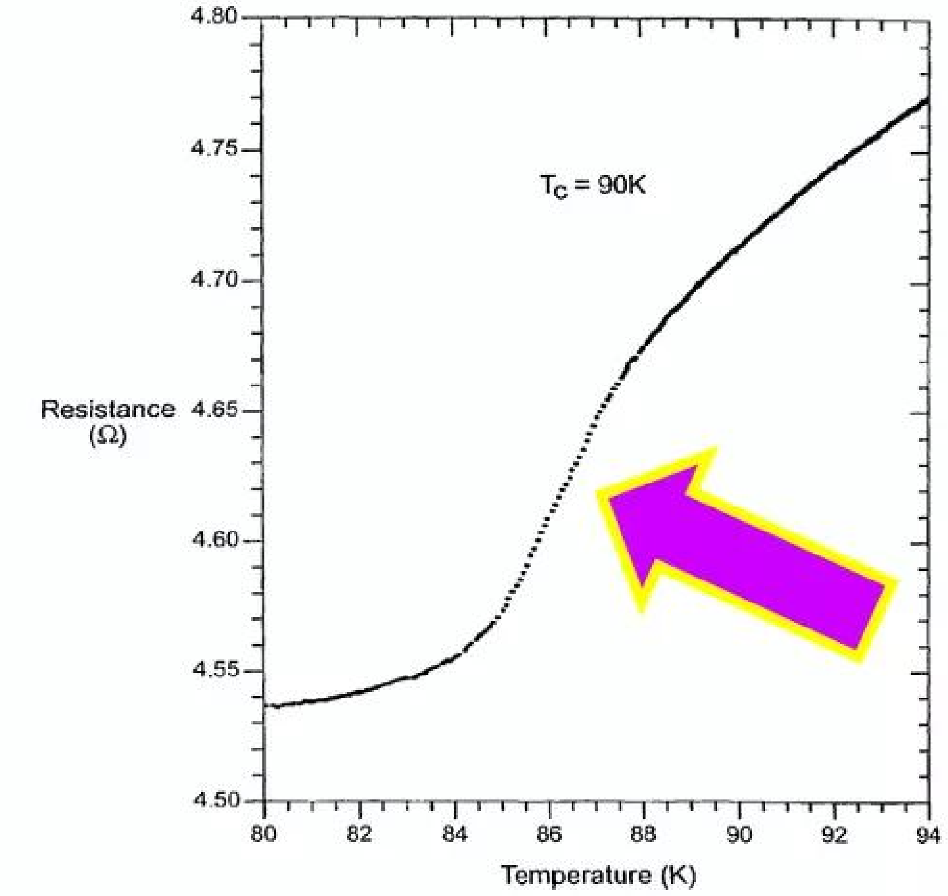

FIG._11A

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Tripodi patent was filed in 2001; USPTO issued in 2006

Method and apparatus for HT superconductivity in Hydrogen-loaded Pd

Excerpts (from Column 13 Lines 31 - 44 in US patent):

✓ **"FIG. 11B shows the electrical resistance measurements of a sample having a phase transition at 100 K that is indicative of a multi-domain sample having a superconducting domain with a critical temperature of 100 K. And finally, FIG. 11C shows the electrical resistance measurements of a sample having a phase transition at 272.5 K that is indicative of a multi-domain sample having a superconducting domain with a critical temperature of 272.5 K. For each of these samples, the length of the superconducting domain can be determined from the size of the resistance drop near the critical temperature using Eq. 6, and the stoichiometric loading ratio can be determined from the log-log plot of critical temperature versus stoichiometric ratio shown in FIG. 9."**

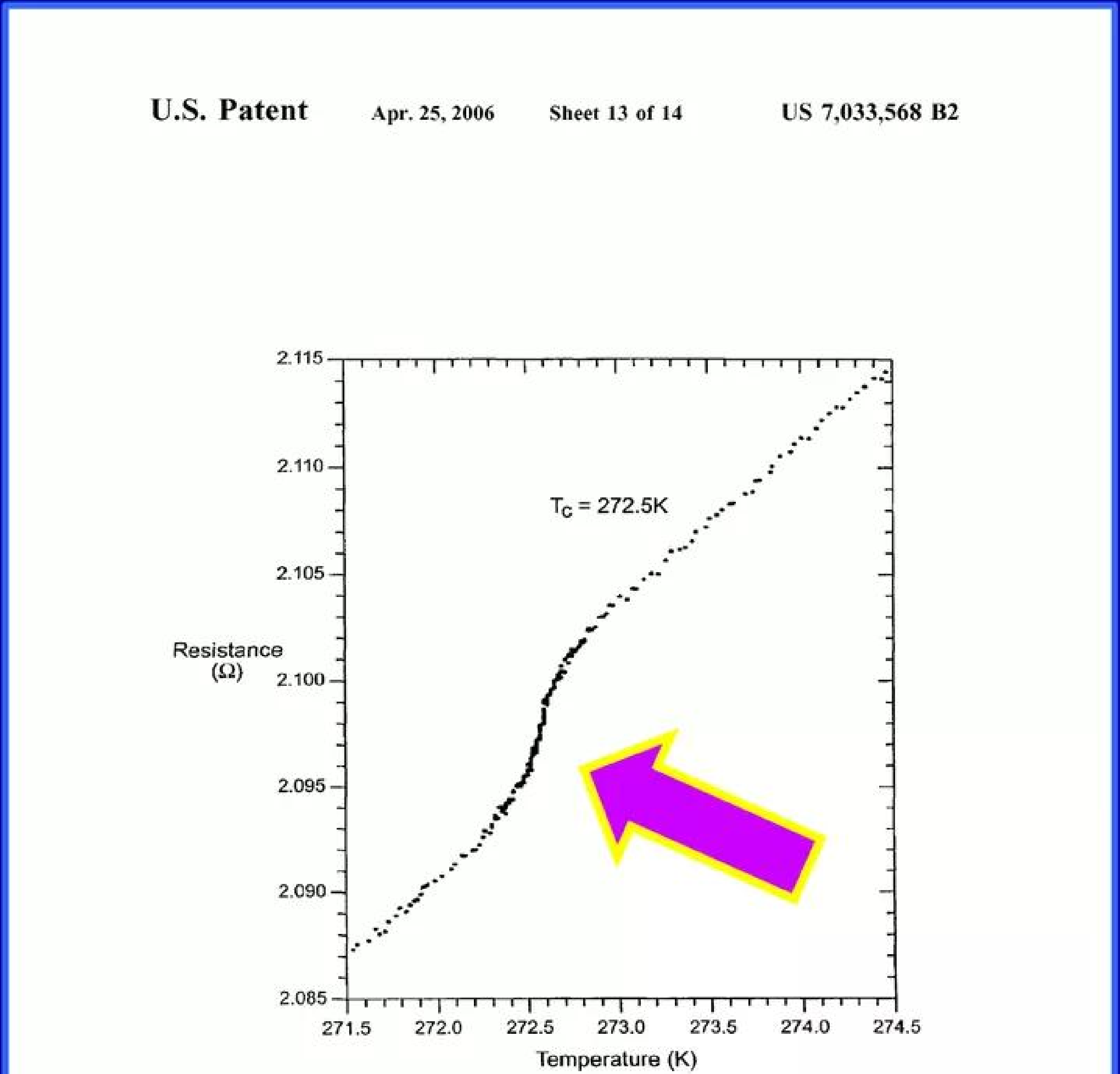


FIG._11C

Lattice Energy LLC

Lipson conference presentation at ICCF-12 in Nov. 2005

Evidence for superconductivity in Hydrogen-loaded Pd and Pd/PdO

Conference presentation:

"Evidence of superstochiometric H/D LENR active sites and high temperature superconductivity in a Hydrogen-cycled Pd/PdO"
A. Lipson, C. Castano, G. Miley, B. Lyakhov, A. Tsivadze, and A. Mitin
ICCF-12, Yokohama, Japan November 27 – December 3, 2005
CONDENSED MATTER NUCLEAR SCIENCE
Proceedings of the Twelfth International Conference on Cold Fusion
A. Takahashi, K. Ota, and Y. Iwamura, eds., pp. 367 - 376
World Scientific Publishing Co. Pte. Ltd (2006)
http://www.worldscientific.com/doi/pdf/10.1142/9789812772985_fmatter
http://lenr-canr.org/acrobat/LipsonAGevidenceofa.pdf [final version published in 2006 differs slightly]

Abstract (quoting directly from ICCF-12 conference Proceedings published by World Scientific):

"Electron transport and magnetic properties have been studied in a 12.5 μm thick Pd foil with a thermally grown oxide and low-residual concentration of Hydrogen. This foil was deformed by cycling across the Pd hydride miscibility gap and the residual hydrogen was trapped at dislocation cores. Anomalies of both resistance and magnetic susceptibility have been observed below 70 K, indicating the appearance of excess conductivity and a diamagnetic response that we interpret in terms of filamentary superconductivity. This anomalies are attributed to a condensed Hydrogen-rich phase at dislocation cores. The role of Deuterium rich dislocation cores as LENR active sites is discussed."

Lattice Energy LLC

Lipson conference presentation at ICCF-12 in Nov. 2005

Published experimental data suggests that SC occurs in tiny regions

- ✓ **Reiterating:** in May-Sept. 2005, while further elaborating Widom-Larsen theory of LENRs to explain unique characteristic involving suppression of high-energy gamma emissions that has been observed in LENR experiments for >20 years, Widom and I saw tantalizing theoretical indications that anomalously high conductivity anomalies might appear in vicinity of many-body 'patches' of entangled, collectively oscillating protons (or homogenous deuterons, tritons) at local E-field values close to field-strength thresholds needed for electroweak neutron production. Not wishing to clutter our paper (http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf) with tangentially related issues, we simply remarked on pp. 2 that, "...added heavy electrons produce an anomalously high surface conductivity at the LENR threshold."

- ✓ In Nov. - Dec. 2005, Andrei Lipson (Russian Academy of Science, Moscow) presented new experimental results (mentioned later herein) at ICCF-12 conference in Yokohama, Japan, regarding what appeared to be HT superconductivity observed in subset of small regions in a Hydrogen-cycled 12.5 *μm* thick Pd/PdO foil.

  Synopsis of ICCF-12 conference report: Lipson *et al.* stated that, "...electron properties of hydrogen-dominant bulk Pd hydrides with x > 1 have not been studied previously because these compounds are unstable at ambient conditions. However, the effect [of] x on the critical temperature, T_c, of PdH_x over the range of $0.8 < x < 1.0$ is to increase T_c from 1 to 8 K. Within the context of this past work, further increases of x above 1 locally at dislocation cores is expected to increase T_c well above the bulk PdH_x value. However, the volume fraction of the compressed hydrogen-rich phase must be high within the Pd [bulk] matrix."

  Interjecting a Lattice comment: "dislocation cores" are open voids in Pd metal created by Hydrogen cycling, i.e., loading and deloading of protons into and out-of material-specific interstitial sites located within a bulk Pd lattice

  "Recently, a diamagnetic susceptibility contribution has been observed in hydride-cycled bulk Pd with (x) ~10^{-4} [H]/[Pd] (see A. Lipson *et al.*, *Phys. Lett. A* 339 pp. 314 - 2005). The volume fraction of this phase was estimated at ~10^{-4}. Because of the low-volume fraction the diamagnetic response was not observed directly, but only after subtraction of the host Pd paramagnetic susceptibility. We have increased the volume fraction by cycling a thin Pd foil with a thermally grown oxide layer to ... constrain[ed] the Pd lattice during hydride cycling and prevent dislocation annihilation at surface ... [and] increase the density of dislocation loops near the Pd-oxide interface"

Lattice Energy LLC

Lipson conference presentation at ICCF-12 in Nov. 2005

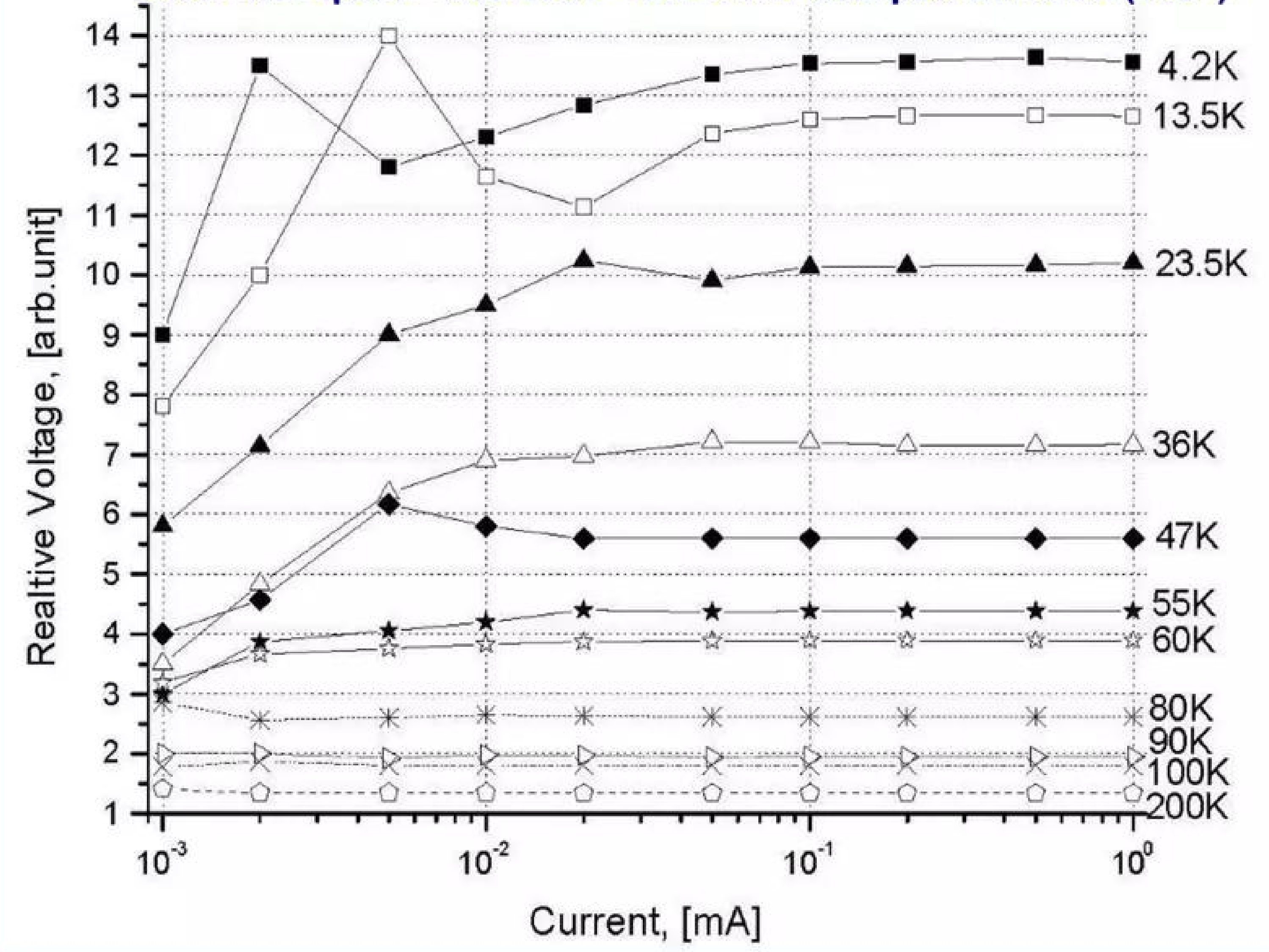
Conjectured that SC occurs in tiny regions with high local H/Pd ratios

Continued selected quotes from Lipson *et al*. (ICCF-12):

- ✓ **"In summary, we have observed anomalies in the electron transport and magnetic properties in a deformed Pd foil with a thermally grown oxide layer and a small residual hydrogen concentration trapped at dislocations. The anomalies are consistent with a filamentary superconducting network that we attribute to the condensation of the trapped hydrogen into a metallic-like phase within the dislocation core. This phase represents a hydrogen dominant metallic alloy, where both hydrogen and Palladium atoms may participate in common overlapping bands. Finally, we note that the presence of non-stoichiometric Oxygen near the Pd-oxide layer interface may enhance electron-phonon coupling and therefore increase the critical temperature, similar to the cuprates ... Note that real critical temperature of weakly linked superconducting filaments of condensed Hydrogen/Deuterium phase would be much higher than T_c ~ 70 K, suggesting superconducting state at room temperature that is projected for metallic Hydrogen (Lipson *ibid.* 2005) ... Deep dislocation cores in Pd could be considered as a H/D-dominant Pd hydride (x = H/Pd ~ 2.0) sites suggesting HTSC properties ... Metallic H/D superfluid suggests dramatic enhancement of quantum entanglement between Deuterons at such sites."**

Note

Source: Lipson *et al*. ICCF-12 PowerPoint presentation (2005)



Quoting from Lipson *et al.* re above Figure: "... enhanced electron transport properties of the Pd/PdO:H_2 sample are supported by the $V(I)$ characteristics shown in Fig. 3. The normalized voltage (Pd/PdO:H_2 over Pd/PdO) is plotted versus DC current over the temperature range 4.2 < T < 203 K. The non-linear behavior at low current (< 0.01 mA) and low temperature (≤ 50 K) indicates enhanced transport properties consistent with uncorrelated supercurrents that break down at high temperature (T ≥ 67 K) ... Similar filamentary superconductivity has previously been observed in high-T_c superconductors."

Lattice Energy LLC

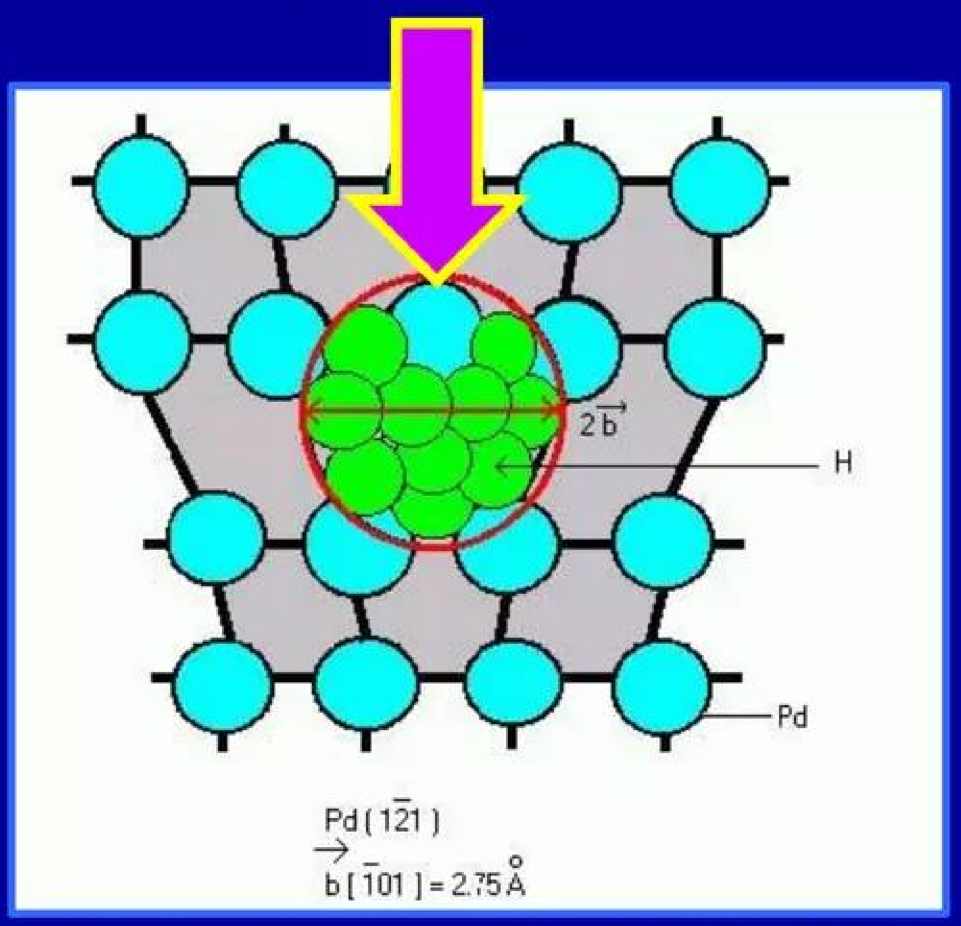
Lipson conference presentation at ICCF-12 in Nov. 2005

Conjectured that SC occurs in tiny regions with high local H/Pd ratios

Quotes from "Summary of Results," "Conclusions" in Lipson *et al.*:

- ✓ **"Pd:H_x and Pd/PdO:H_x samples after H-cycling and annealing at T = 573 K contain only condensed hydrogen phase inside deep dislocation cores: x = H/Pd = (4 - 6) x 10^{-4} with respect to the sample. Inside dislocation nanotube [itself] x = H/Pd ~1.4 - 1.8"**
- ✓ **"Accordingly to SQUID measurements the H_2-cycled PdH_x single crystal sample demonstrates signature of a weak Type II superconductivity, involving condensed hydrogen phase in deep dislocation cores [PdH_x-Pd] below 30 K"**
- ✓ **"Results of both magnetic and transport measurements in Pd/PdO:Hx are suggested superconducting transition below 70 K. Reproducible Meissner effect was obtained at H ≤ 1.0 Oe in AC field (f = 1 kHz): Type II 2-dimensional filamentary SC"**
- ✓ **"Deep dislocation cores in Pd could be considered as a H dominant Pd hydride (x = H/Pd > 1.0) sites showing HTSC properties"**
- ✓ **"Large optic phonon energy ($\hbar\omega_D$ ≥ 100 meV) resulting in a most effective lattice-nuclei energy transfer"**
- ✓ **"Metallic H/D superfluid suggests dramatic enhancement of quantum entanglement between deuterons at those sites"**

Lattice comments: Lipson *et al.*'s "dislocation core" is really an open void within the Pd metal, more likely having a very roughly ovoid/spherical interior geometry rather than being strictly only cylindrical. Moreover, surface plasmon electrons will be present therein, so Widom-Larsen theory of LENRs will apply and operate inside such small structures; hydrogen-isotope-filled void's interior space can also operate as a resonant E-M cavity



Source: Lipson *et al.*, ICCF-12 (2005) Presentation Slide #10

Quoting caption: "Edge dislocation core in Pd with H_n-"metallic" hydrogen phase: dislocation core is a nanotube with radius R_H = b (Burgers vector)"

Lattice Energy LLC

Anomalous voltage fluctuations seen in recent experiments

McKubre (SRI) reported such data in LiOD P&F-type electrolytic cells

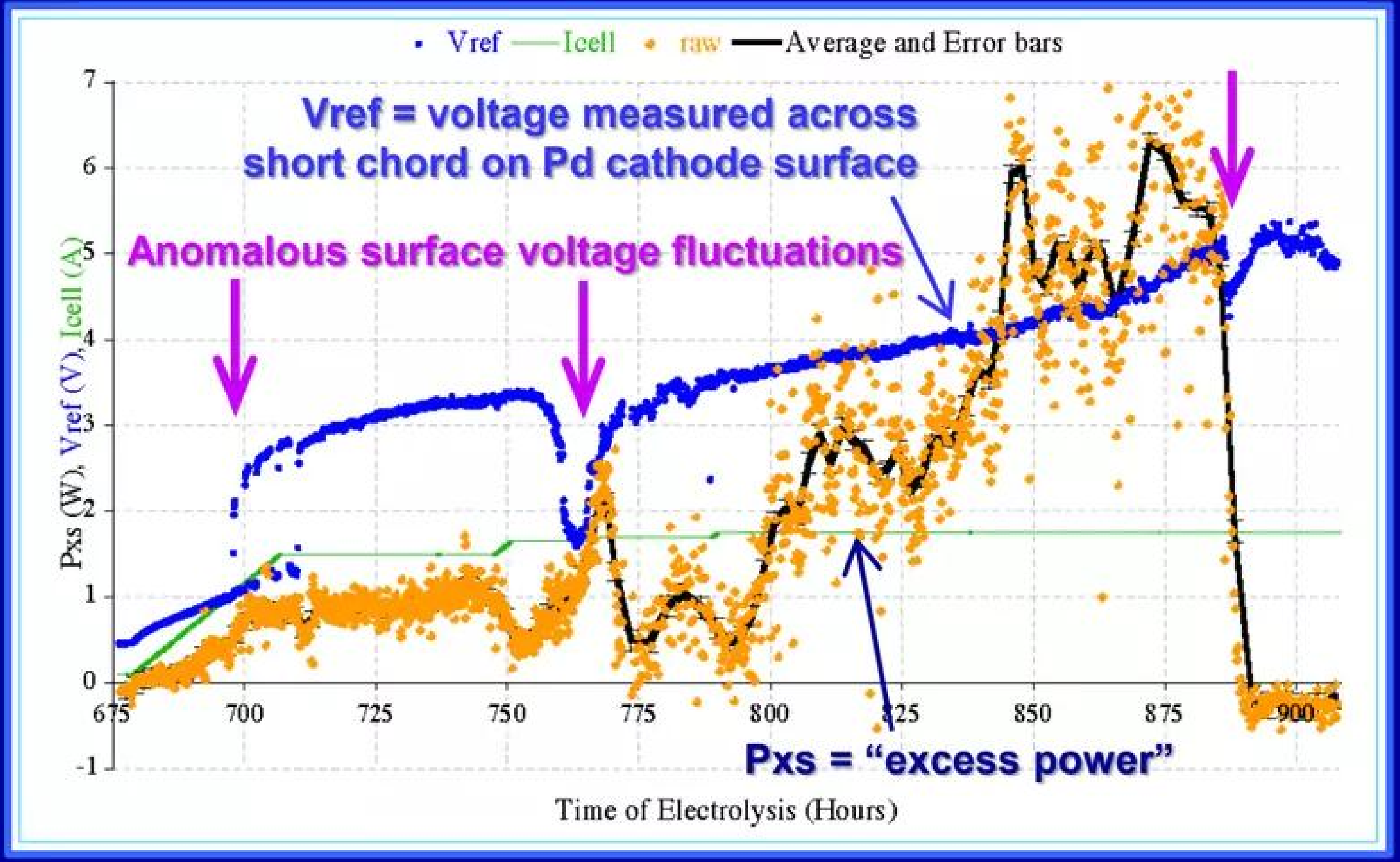
Direct quotes from private Mckubre communication in 2012:

"We (SRI) spent a lot of time attempting to interrogate the cathode/electrolyte interface in active FP cells both in respect of thermodynamics (voltage or 'overvoltage' in electrochemist jargon) and kinetics (interfacial impedance and even non-linear harmonic impedance spectroscopy - HIS). It turns out that both (or all three including HIS) change leading up to, during and after an excess heat event."

"The curve below is one I often show [Note: see chart to right] This is P15 (1M LiOD + 200 ppm Al)) - running at 10 and 12 W of total input power (electrochemistry + compensation heater). The blue points are data taken as the potential difference between the cathode (at the current specified) and a small point of Pd (or Pt) immediately adjacent to (and not touching) the cathode. Here we have a voltage (or 'resistance' if you divide by current) that is relevant to the cathode, under conditions before, during and after a P*xs* event that is significant (up to 6W or 50% of total input power) and prolonged (~200 hour)."

"The blue points are fascinating. Just as Pxs gets to ~1W the cathode voltage enters a bimodal condition like a turbulent bifurcation. The voltage swings between states that are ~1.5V apart which is huge for electrochemistry. Somewhat associated with the first big spike in Pxs (at ~770h) the now fully stabilized higher voltage surface phase, destabilizes for a period, and then re-forms. Is this a voltage effect (cathode thermodynamics?) or an impedance effect (cathode kinetics?) We could know from additional diagnostics but in this case we don't."

Lattice comments: McKubre's anomalous voltage fluctuation events measured on a Pd cathode surface are conceptually very similar to the ultrathin Pd-wire data collected by Selvaggi and reported by Miley *et al*. at ICONE in 2000. Also please note that it is well-known in field that H/Pd or D/Pd loading ratios can substantially exceed 1.0 in tiny regions on Pd surface



Source: extracted and adapted from M. McKubre – Slide #11 at ICCF-15 Rome, Italy (October 2009)

http://lenr-canr.org/acrobat/McKubreMCHcoldfusiona.pdf

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Recap: there is experimental evidence for SC in LENRs

Effects appear in PdH_x, PdD_x and PdH_x/PdO from cryo to above 273°K

Superconductivity has been known in Palladium hydrides since early 1970s

Slide #s	Type of experiment	Researcher(s) and year reported	Material(s) range of temperatures(s) when effects are measured	Material/isotope in which effects are observed	Anomalous experimental effect(s)	Comments
5 and 50 - 52	Ultrathin 50 μm metal wire in current-driven electrolytic cell with D_2O (10^{-5} M $CaSO_4$)	Selvaggi: 2000 ICONE conference report	Room temp or above (> 273 K)	Pure Pd: PdDx	Large, rapid resistivity fluctuations	Correlated with calorimetric macro excess heat burst
6 and 53 - 61	Two alternative preferred system embodiments: metal cathode was loaded w. hydrogen isotope in electrolytic cell with H_2O (10^{-5} M Hg_2SO_4); or, metal thin-film target hit with accelerated hydrogenous ions in pressure chamber	Tripodi *et al.*: two papers published in *Physica C* in 2003 and 2004; US Patent issued in 2006	Removed from electrolytic cell; then measurements were made at low cryogenic temps up to room temp (*Tc* > 273 K) or above, e.g. 400K	Pure Pd: PdHx Claimed alternative embodiments include PdDx	Multiple measurements were consistent with SC including Meissner effect; please see 2006 US patent and associated papers for details	Some measurements indicate possible RTSC observed; claimed some effects were supposedly observed for as long as 24 hours after removal from loading cell
62 - 65	12.5 μm thick metal foil; thermally grown oxide; loaded w. hydrogen isotope in electrolytic cell with H_2O (1M Li_2SO_4)	Lipson *et al.:* 2005 ICCF-12 conference report	Removed from electrolytic cell; then measurements made at low cryogenic temps up to T < ~67 K	Pure Pd: PdHx and PdHx:PdO heterostructres	Multiple measurements were consistent with SC; see full presentation	Conjectured Type II filamentary superconductor; observed Meissner effect
66	Macroscopic metal cathode in electrolytic cell with D_2O (1M LiOD with 200 ppm Al)	McKubre: 2009 ICCF-15 conference report	Room temp or above (> 273 K)	Pure Pd: PdDx	Large, rapid resistivity fluctuations measured across cathode surface	Correlated with large up/down macro fluctuations in calorimetric excess heat

Summary comments: altogether, viewed through the conceptual lens of the Widom-Larsen theory of LENRs, these varied experimental observations suggest to the author that some form of evanescent high temperature superconductivity cold potentially be associated with heavy-SP electron patches that form on surfaces that can, under proper conditions, become LENR-active sites

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Recap: possible experimental evidence for SC in LENRs

Effects appear in PdH_x, PdD_x and PdH_x /PdO from cryo to above 273°K

Note that Tripodi's amazing measurements have never been refuted

Renewed interest in Tripodi's earlier work became apparent in 2011 - 2012

APS March Meeting 2012, Volume 57, Number 1, Monday - Friday, February 27 - March 2 2012; Boston, MA.

Please take special note: new work below is for case of PdHx where 0 ≤ x ≤ 1; Tripodi and Lipson both conjectured that superconductivity effects should become progressively stronger as x increases further and further above x = 1, i.e., local values of hydrogen loading >> 1

Session Q21: Novel Superconductivity in New and Low Dimensional Materials, 12:15 AM - 12:27 PM, Wednesday, February 29, 2012 Room: 254A **Authors:** P. Buczek *et al.*

"Elementary excitations and elusive superconductivity in palladium hydride --- *ab initio* perspective. I. Paramagnons "

"Motivated by a experimental reports on possible high temperature superconductivity in palladium hydride [Tripodi *et al., Physica C* 388-389, 571 (2003)], we present a first principle study of spin fluctuations, electron-phonon coupling and critical temperature in PdH_x, 0 ≤ x ≤ 1. A prerequisite for any qualitative study of exchange-enhanced materials is the knowledge of spin flip fluctuation spectrum. It is generally believed [Berk & Schrieffer, *Phys. Rev. Lett.*, 17, 433 (1966)] that the ferromagnetic-like paramagnons of Pd are destructive for the conventional, i.e. *s*-wave, superconductivity. We describe them using linear response time dependent density functional theory, recently implemented to study complex metals [Buczek *et al., Phys. Rev. Lett.* 105, 097205 (2010)]. We find that hydrogenation suppresses the intense spin fluctuations of pure Pd, driving it away from a magnetic critical point. Under the assumption of *s*-wave pairing, this could lead to the formation of the superconducting state. The *ab initio* estimated electron-phonon coupling is strong enough to support superconductivity. Please look for the complementary contribution of Christophe Bersier."

Session Q21: Novel Superconductivity in New and Low Dimensional Materials, 12:27 AM - 12:39 PM, Wednesday, February 29, 2012 Room: 254A **Authors:** C. Bersier *et al.*

"Elementary excitations and elusive superconductivity in palladium hydride --- *ab initio* perspective. II. Phonons"

"Motivated by a experimental reports on possible high temperature superconductivity in palladium hydride [Tripodi *et al., Physica C* 388-389, 571 (2003)], we present a first principle study of spin fluctuations, electron-phonon coupling and critical temperature (Tc) in PdHx , 0 ≤ x ≤ 1. Our results described in terms of (i) electronic structure, (ii) phonon density of states and (iii) Eliashberg function show that the hydrogenation of Pd clearly enhance the electron-phonon coupling in this material. Assuming phonons to be the driving force for superconductivity, *fcc* Pd features a vanishingly small Tc, while for the stoichiometric *x* = 1 PdH the resulting Tc is around 10 K in agreement with experiment. It is generally believed [Berk & Schrieffer, *Phys. Rev. Lett.* 17, 433 (1966)] that intense spin-&flip fluctuations of Pd are destructive for the conventional, i.e. *s*-wave, superconductivity. However, the H doping leads to a drastic reduction of spin-flip scattering. Please look for complementary presentation of Pawel Buczek."

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Widom-Larsen theory re superconductivity and LENRs

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Tripodi *et al.'s* 2003 - 2004 PdH_x HTSC data not refuted

New 2012 theoretical work provides support for Tripodi's claims

- ✓ While startling and seemingly incredible, it appears that Tripodi *et al.'s* claimed experimental measurements that were published in *Physica C* in 2003 - 2004 --- which showed superconductivity occurring at or above room temperature in local regions of pure Palladium having high stoichiometric PdH_x ratios > 1.0 --- while questioned by some researchers, have not been decisively refuted to date. Furthermore, Lipson *et al.'s* reported experimental work (2005) appears to bolster Tripodi *et al.,* at least in part
- ✓ Possibility that these measurements --- which suggest that superconductivity might be able to occur at amazingly high temperatures in Palladium Hydrides --- could well have been correct is supported by recent theoretical interest in Tripodi *et al.'s* work by academic researchers located in Germany and the U.K. (P. Buczek *et al.* and C. Bersier *et al.* --- see Slide #68) that was reported at the March 2012 APS meeting in Boston, MA in a session titled, "Novel Superconductivity in New and Low Dimensional Materials"
- ✓ That being the case, for the purpose of this discussion let us now assume that Tripodi *et al.'s* and Lipson *et al.'s* experimental measurements were correct and that a form of high temperature superconductivity can occur in 2-D or 3-D regions of Palladium Hydride material in which PdH_x ratios are very high, i.e., x >1.0 and especially x > 1.6
- ✓ Question: is there published independent experimental evidence which supports notion that high stoichiometric PdHx ratios with x > 1.0 can occur in types of ~2-D many-body surface patches envisioned in the Widom-Larsen theory of condensed matter LENRs?

Mitsui *et al.* (2003) see high surface PdH_x ratios with STM

Suggests that similarly high ratios would also occur in W-L patches

- ✓ **"Hydrogen absorption and diffusion on Pd(111)"**
  T. Mitsui *et al.*
  ***Surface Science* 540 pp. 5 - 11 (2003)**
  http://144.206.159.178/ft/976/183940/4699801.pdf

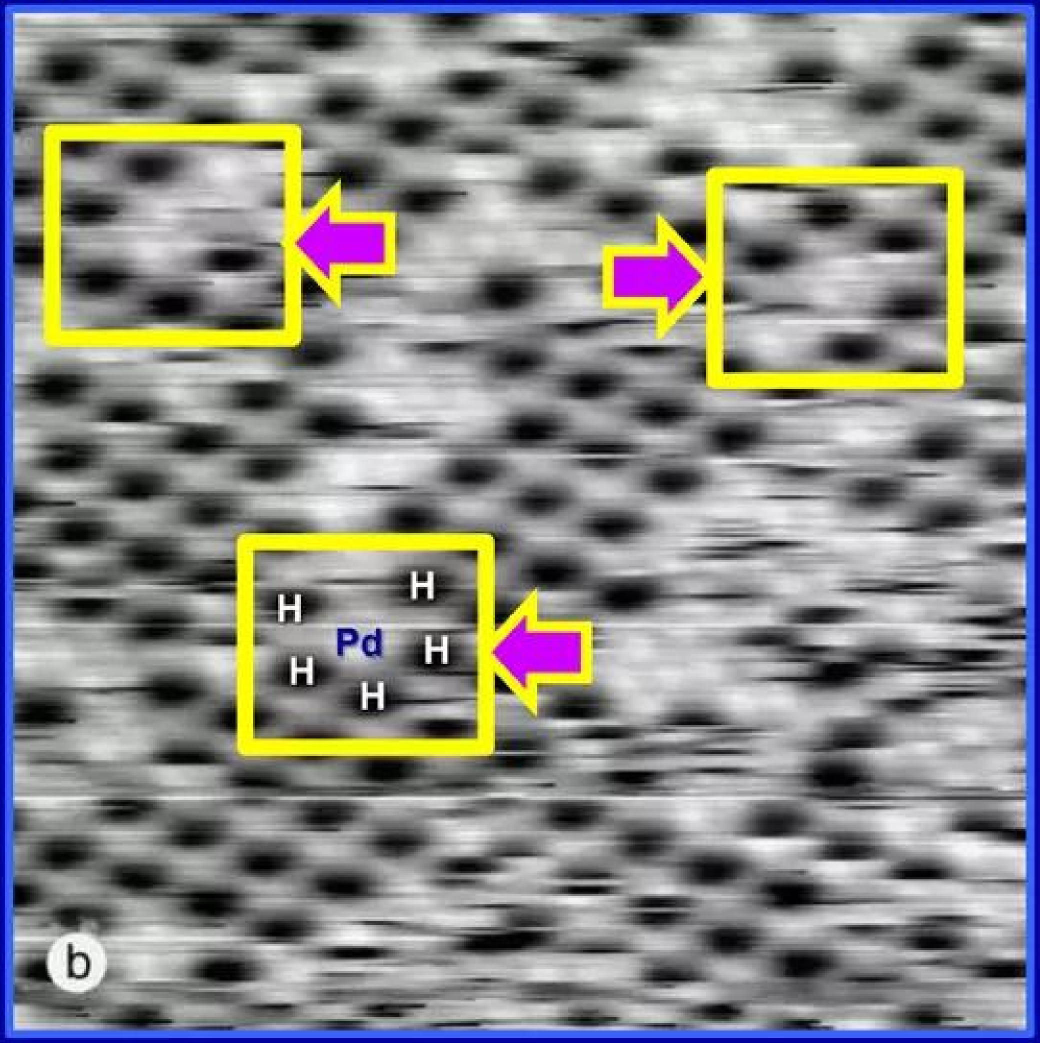
  Abstract: "The adsorption, diffusion and ordering of hydrogen on Pd(111) was studied by scanning tunneling microscopy in the temperature range of 37 - 90 K. At low coverage isolated hydrogen atoms were observed. They formed √3 x √3-1H islands as the coverage increased. Above 1/3 monolayer (ML) coverage areas of a new phase with √3 x √3 -2H structure were formed, with both structures coexisting between 1/3 and 2/3 ML. Finally a 1 x 1 structure was formed after high exposures of hydrogen above 50 K, with a coverage close to 1 ML. Atomically resolved images reveal that H binds to fcc hollow sites."

  Quoting excerpt "… to our knowledge, an STM study of hydrogen adsorption on a closed packed (111) metal surface has [previously] not been reported."

- ✓ **Lattice comment: simple visual inspection of STM image in adapted version of Fig. 1 reveals that under Mitsui *et al.'s* experimental conditions, PdH_x ratios at many surface sites would appear to be comfortably above the critical value of x > 1.0 necessary for LT and HT superconductivity that was conjectured by both Tripodi and Lipson. In fact, PdH_x ratios at some sites can apparently range perhaps as high as x = 5.0 (again, please inspect the adapted Figure 1. to right)**

  Therefore, similarly high PdH_x ratios would seem to be plausible in the case of high % surface coverage of hydrogen atoms (protons) on fully-loaded Pd(111) surfaces at room temperature of 273 K and beyond. Thus, high PdH_x ratios could reasonably be expected to occur within the ~2-D many-body, entangled hydrogenous patches conjectured in the Widom-Larsen theory of LENRs

STM image of H on Pd(111) adapted from: Fig. 1 in Mitsui *et al.*, *Surface Science* (2003)



Quoting from Fig. 1 caption in paper: "Fig. 1. (a) 10 x 10 nm image of the Pd(111) surface after a short exposure to H_2 gas. Isolated H atoms are the dark spots, corresponding to 15 pm depressions. The atoms diffuse thermally and also by the influence of the tip, forming the dark streaks seen in the image. (b) At a coverage of 0.2 ML islands with √3 x √3 *R*30° structure are formed. The H atoms are now stable and do not diffuse. The influence of the tip is now negligible. The Pd atoms are the bright spots between the H islands, with a corrugation of ~2 pm. The H site, at the center of an upward pointing triangle of Pd atoms is the fcc hollow. Tunneling conditions: ~45 mV tip bias and 11 nA current."

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Sljivancanin *et al*. (2011) studied H patches on graphene

Found that larger many-body CH_x clusters strongly favored on surfaces

- ✓ "Structure and stability of small H clusters on graphene"
  Z. Sljivancanin *et al*.
  Physical Review B 83 pp. 205426 - 205436 (2011)
  http://arxiv.org/pdf/1102.4984v2.pdf

  Abstract: "The structure and stability of small hydrogen clusters adsorbed on graphene is studied by means of density functional theory (DFT) calculations. Clusters containing up to six H atoms are investigated systematically, with the clusters having either all H atoms on one side of the graphene sheet (cis-clusters) or having the H atoms on both sides in an alternating manner (trans-clusters). The most stable cis-clusters found have H atoms in ortho- and para-positions with respect to each other (two H's on neighboring or diagonally opposite carbon positions within one carbon hexagon), while the most stable trans-clusters found have H atoms in ortho-trans-positions with respect to each other (two H's on neighboring carbon positions, but on opposite sides of the graphene). Very stable trans-clusters with 13 - 22 H atoms were identified by optimizing the number of H atoms in ortho-trans-positions and thereby the number of closed, H-covered carbon hexagons. For the cis-clusters, the associative H_2 desorption was investigated. Generally, the desorption with the lowest activation energy proceeds via para-cis-dimer states, i.e., involving somewhere in the H clusters two H atoms that are positioned on opposite sites within one carbon hexagon. H_2 desorption from clusters lacking such H pairs is calculated to occur via hydrogen diffusion causing the formation of para-cis-dimer states. Studying the diffusion events showed a strong dependence of the diffusion energy barriers on the reaction energies and a general odd-even dependence on the number of H atoms in the cis-clusters.."

  Quoting: "According to experiments, bigger structures will form when graphite or graphene are exposed to higher H doses. These structures, highly relevant for possible technological applications, are much less investigated than dimers…H adsorption on graphene in compact cis-cluster structures, described in Sec. III, is thermodynamically preferential compared to the adsorption of isolated H atoms…binding energy per H atom in general increases with the size of the clusters…Graphane, which can be considered as an infinite trans-cluster with no edge atoms, thus represents the highest achievable cluster stability."

- ✓ Lattice comment: work of Z. Sljivancanin *et al*. clearly shows that growth of progressively larger surface patches of hydrogen (protons) on Graphene are strongly favored energetically, finally culminating with a fully-loaded hydrogen supercluster that effectively covers most of the surface of what is referred to as Graphane. By analogy with metallic hydride systems, one could conjecture that these surface protons would be collectively oscillating and mutually entangled with each other and with surface plasmon electron excitations that are now definitely known to be present on Graphene ("Optical nano-imaging of gate-tunable graphene plasmons," J. Chen *et al. Nature* doi:10.1038/nature11254 published online 20 June 2012; and "Gate-tuning of graphene plasmons revealed by infrared nano-imaging" Z. Fei *et al*. in very same issue). Thus the Widom-Larsen theory also very likely applies here

V/R fluctuations seen by Selvaggi (2000) & McKubre (2009)

Consistent with HTSC in Pd but are not definitive all by themselves

✓ **"Voltage noise and surface current fluctuations in the superconducting surface sheath"**
J. Scola *et al.*
***Physical Review B* 72 pp. 012507 - 012511 (2005)**
http://arxiv.org/pdf/cond-mat/0505756.pdf

Abstract: "We report the first measurements of the voltage noise in the surface superconductivity state of a type-II superconductor. We present strong evidences that surface vortices generates surface current fluctuations whose magnitude can be modified by the pinning ability of the surface. Simple two stage mechanism governed by current conservation appears to describe the data. We conclude that large voltage fluctuations induced by surface vortices exist while the bulk is metallic. Furthermore, this experiment shows that sole surface current fluctuations can account for the noise observed even in the presence of vortices in the bulk."

Quoting excerpts: "In the surface superconductivity state, surface currents naturally coexist with a metallic bulk ... To our knowledge, the noise in the surface superconductivity state has not been reported so far. We show here that large voltage fluctuations do exist in this regime. Since it is made clear that they originate from the surface (approximately 0.01% of the total volume), a demonstration of the relevance of the two-stage surface/bulk noise mechanism is brought .. one can speculate that, during the flux spots motion, many instabilities occur close the surface due to the local release of boundary conditions … Up to now, only the surface current flowing in a very thin layer (about $\xi \approx 30$ nm compared to a sample thickness of $10^4 \times \xi$) is the fluctuating quantity … Experimental signatures of this mechanism would be the existence of large voltage noise even without bulk vortices, i.e., in the surface superconducting regime … Whatever the genuine reason is, the central point is that an impressive increase of the surface critical current is observed (fig. 5), whereas the bulk properties are unchanged … To conclude, voltage noise due to flux spots motion in the superconducting surface sheath has been observed. Current conservation induces bulk noisy current whereas the noisy sources were shown to be clearly localized close to the surface. Noise is found to be of the same magnitude as in the conventional mixed state of type II superconductors, and it behaves similarly. This emphasizes the fundamental role of the boundaries in the non-linear response of vortices. "

"Intrinsic noise sources in superconductors near the transition temperature"
M. Galeazzi *et al.*
***Nuclear Instruments and Methods in Physics Research A* 520 pp. 344 - 347 (2004)**
http://www.sciencedirect.com/science/article/pii/S0168900203031620

Quoting extracts there from re Type-I SCs: "There are other possible sources that could contribute to the total noise spectrum. One such source is the fluctuation in the number of superconducting pairs or superconducting order parameter near the transition temperature … superconducting pair density near and below *Tc* increases linearly with decreasing *T* … This leads to a fluctuation in the order parameter and consequently in the number of superconducting pairs that are responsible for a voltage noise in the superconductor … The magnitude of this noise term is biggest at the transition temperature, and decreases symmetrically both above and below it."

Lattice comment: while anomalously large fluctuations in resistance or voltage data reported by Selvaggi and McKubre are in fact consistent with HTSC processes they are not definitive signatures, since other types of processes such as surface LENR thermal events could produce very similar results

Many-body collective effects: key to Widom-Larsen theory

How might one conceptualize quantum systems found in patches?

- ✓ Herein we have described how the Widom-Larsen theory of LENRs operates in nm- to μ-scale collectively oscillating many-body, ~homogenous patches of Q-M entangled protons, deuterons, or tritons (i.e., p^+, d^+, or t^+) found on condensed matter surfaces (see Slides # 8 – 48). For the purpose of discussion, let us conceptually idealize such: (1) hydrogenous patches as being ~contiguous 2-D proton monolayers in an ~circular shape, i.e. a thin disk of strongly-correlated positive charges; and (2) surface plasmon electrons as being an essentially flat ~2-D layer of collectively oscillating, many-body Q-M entangled particles that intrinsically cover an entire substrate surface, i.e. a thin-film of strongly-correlated negative charges

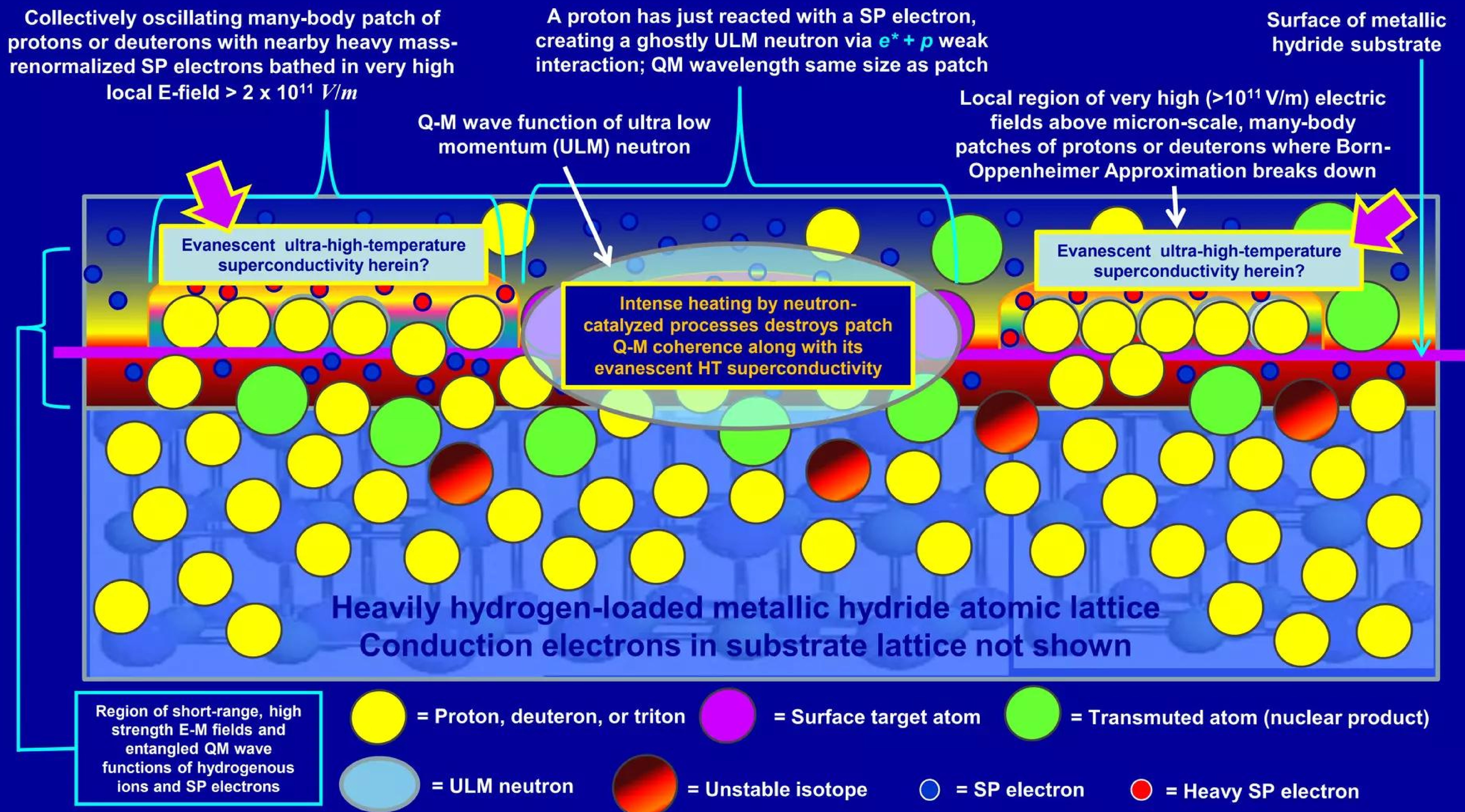
- ✓ Thanks to local breakdown of Born-Oppenheimer approximation in such patches, we have approximately circular surface regions with diameters ranging from several nm to ~100 microns in which electromagnetic coupling is established between ~2-D disks of hydrogenous ions and film of surface plasmon electrons covering a substrate. Once B-O breakdown and local proton-electron E-M coupling occur: (1) proton-coupled SP electrons situated in patches can be conceptualized as thin, ~2-D circular disks; and (2) nuclear-strength local electric fields that are created and established within spatial dimensions of disk-like patches will in turn create local populations of heavy mass-renormalized SP electrons that are also located within such patches

- ✓ In case of hydride-forming metallic substrates (e.g., certain metals such as Pd, Ni, Ti, etc.), it is known that ~2-D, island-like surface structures comprised of hydrogenous ions can form spontaneously once interior, material-specific interstitial sites in bulk lattice have become fully saturated or loaded with ionized hydrogen isotopes. Conceptually, once local nuclear strength E-fields form in a given patch, we have two many-body, ~2-D disk-shaped, Q-M entangled, strongly-correlated subsystems of oppositely charged particles that are mutually coupled to each other via E-M fields and to underlying substrate subsystem

- ✓ We will begin exploring some possible consequences of such conceptualization in the Slides to follow

Collective many-body Q-M effects important in patches

Does patch become an evanescent HTSC just before going nuclear?



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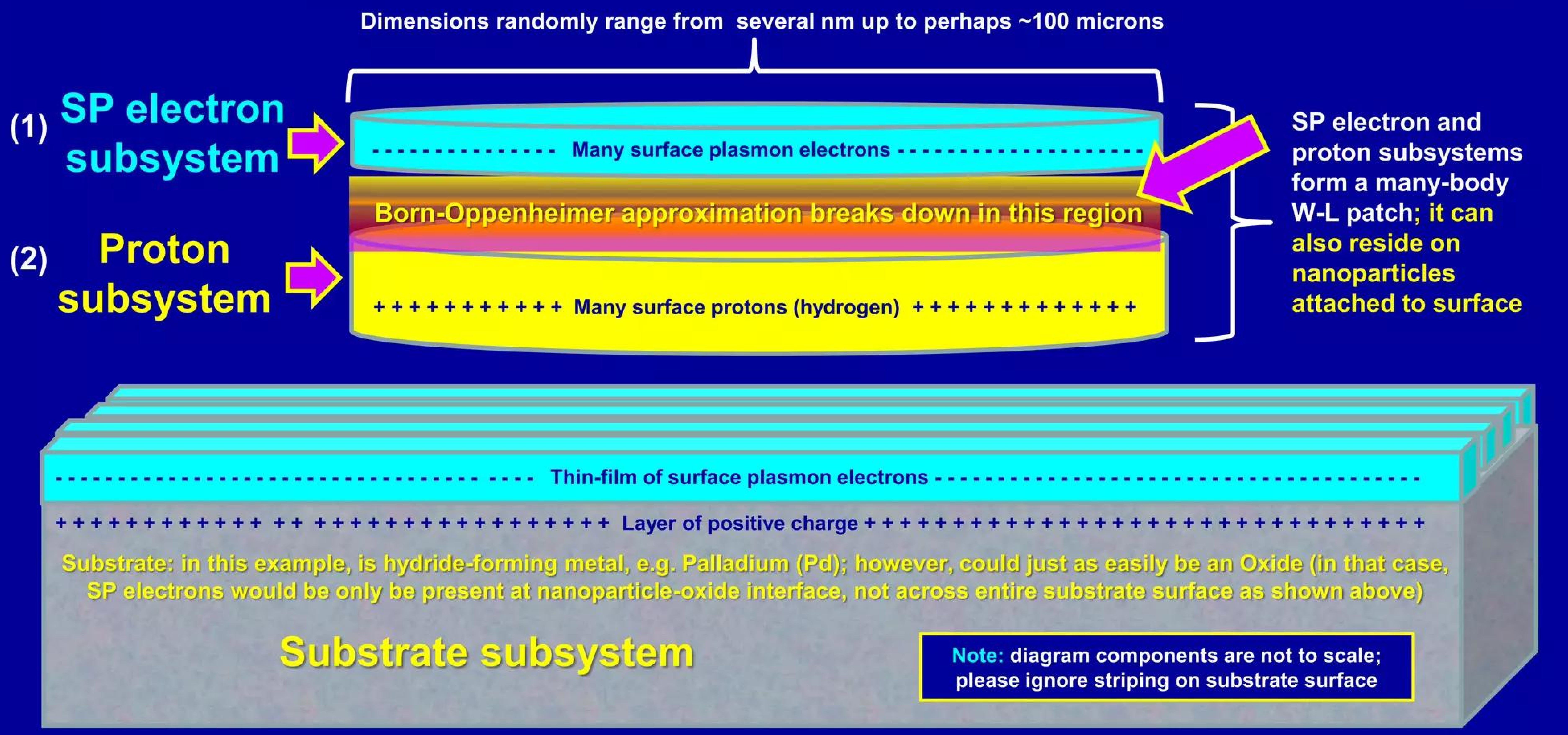
Idealized conceptual elements of a Widom-Larsen patch

Patch comprises two many-body subsystems of interacting particles

(1) Surface plasmon electrons and (2) surface protons, i.e. hydrogenous ions p^+, d^+, or t^+

Particles in subsystems oscillate collectively and are entangled so Q-M wave functions are delocalized



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Conceptual elements of W-L patch situated on substrate

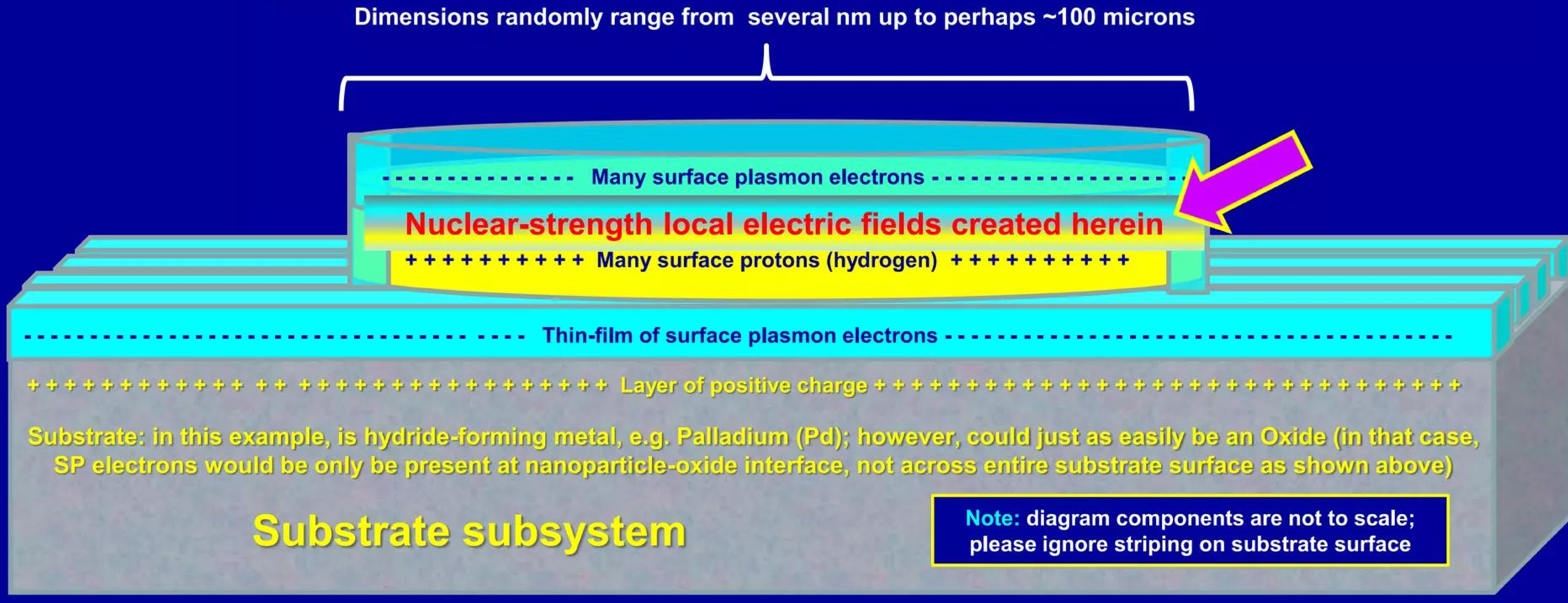
Patch is ready to go but needs input energy to create heavy electrons

E-M fields couple surface plasmons to protons in patch and to SPs on substrate surface

Substrate can be planar surface of bulk material or complex geometric surface of host nanoparticle

Host nanoparticles can be fabricated and affixed on substrate surfaces to optimize and manage E-fields and/or LENR products

Sufficient input energy will create local nuclear-strength E-fields > 10^{11} V/m within the patch



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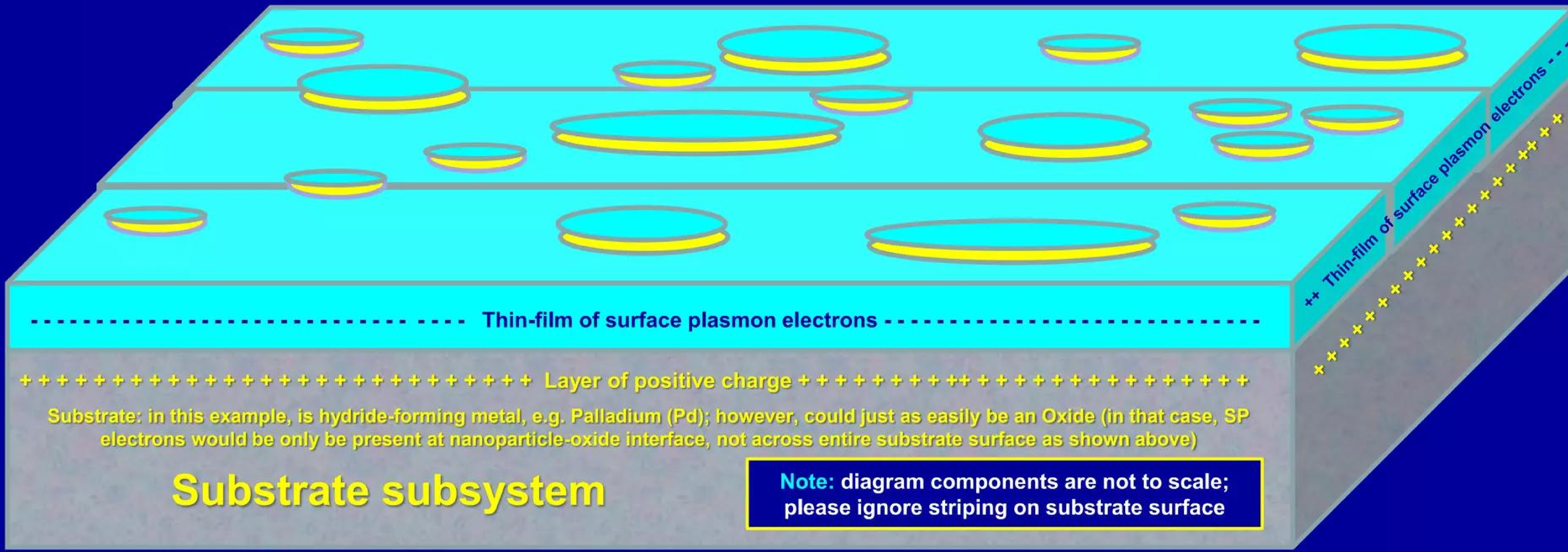
Collection of W-L patches situated on substrate surface

Dimensions and locations vary randomly across surface

Patches are very dynamic evanescent structures that are born and eventually die

Unless local E-field strengths tightly controlled maximum patch lifetime may only be ~400 nanoseconds

Once a given W-L patch goes nuclear it can create a crater



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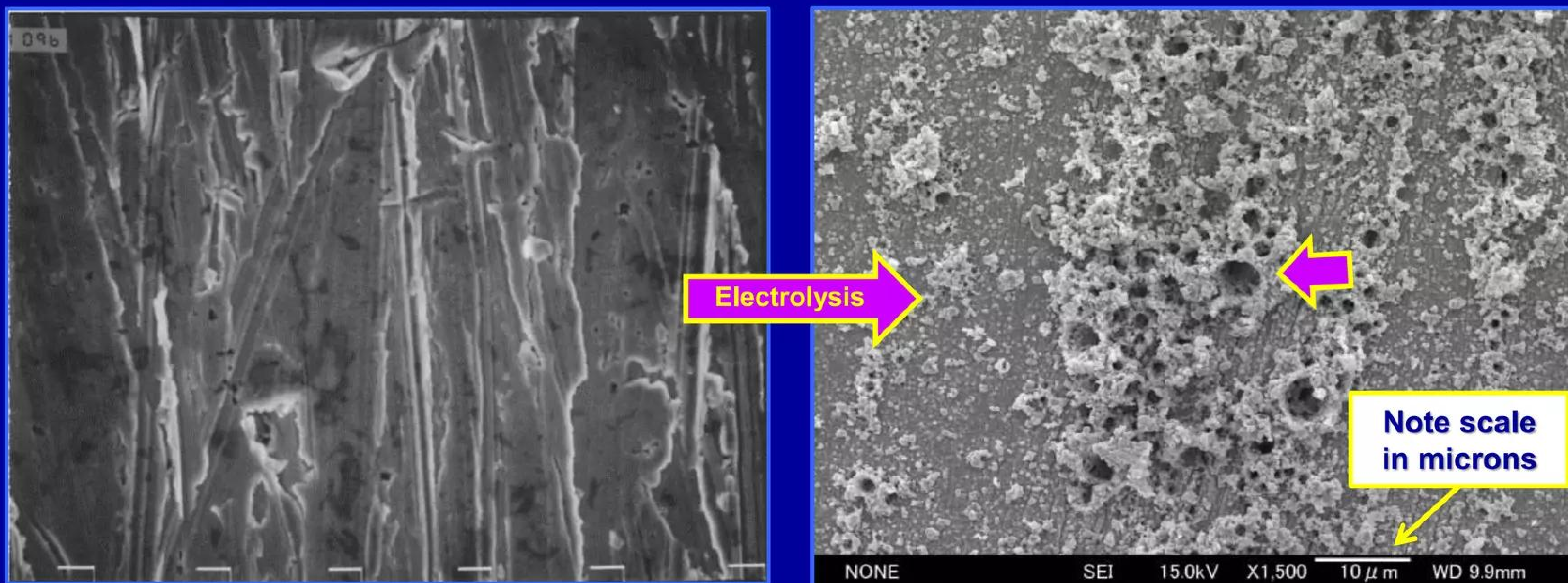
Patch activity telltales are visibly apparent in SEM images

Once a given patch goes nuclear it can create a blow-out crater

Mizuno *et al*. reported on new experiments at ICCF-17 (2012)

Before: relatively smooth surface | **After: rugged terrain on micron length-scales**



Quoting Slide #5 caption in ICCF-17 presentation: "These photo are the Pd electrode before and after the electrolysis. Electrolysis was conducted for a long time, several day or several week. Typical current density was 20mA/cm^2. Here, you see the metal particle (100 nm or less) on the surface after electrolysis. Some of them are less than 10 nano-meter of size."

Source: 41-slide ICCF-17 conference (Aug. 12-17, 2012, Daejeon, Korea) presentation titled, "Theoretical Analysis of Chemically Assisted Nuclear Reactions (CANR) in Nanoparticles," T. Mizuno, M. Okuyama, Y. Ishikawa, and T. Oheki

Copy of slides available at: http://newenergytimes.com/v2/conferences/2012/ICCF17/ICCF-17-Mizuno-Theoretical-Analysis-Slides.pdf

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Summary of key Widom-Larsen patch characteristics

Patch comprised of coupled SP electron and surface proton subsystems

Some type of evanescent in-plane 2-D HTSC could potentially be occurring therein

	Type of particle in subsystem	Are particles in subsystem charged?	Dimensionality	Do particles collectively oscillate?	Are particles entangled?	Comments
Widom-Larsen surface patch Sizes vary randomly - diameters can range from several nm to perhaps up to ~100 microns	Surface plasmon electrons (fermions) decidedly many-body	Yes, -	~2-D reduced	Yes	Yes Q-M wave functions are very delocalized within a patch	Under proper conditions might form a quantum condensate comprised of Cooper pairs quantum confinement in patch *a la* quantum dots
	Surface protons (hydrogen) (fermions) decidedly many-body	Yes, +	~2-D reduced	Yes	Yes Q-M wave functions are very delocalized within a patch	Under proper conditions might form a quantum condensate comprised of Cooper pairs quantum confinement in patch *a la* quantum dots
Substrate material	Mostly neutral atoms except for interstitial absorbed hydrogenous ions that occupy material-specific sites in substrate bulk lattice	No charge-neutral for the most part	Essentially 3-D i.e., bulk material	No	No	Very high nuclear-strength electric fields > 10^{11} V/m present within an energized patch can potentially induce proximity E-M effects in substrate in close contact with that patch

Further Lattice comments: if some type of evanescent HTSC superconductivity truly occurs during the brief lifetime of W-L patches prior to their going nuclear, since such patches are dimensionally ~2-D one can speculate that it would probably be in-plane, somewhat akin to Type-II layered superconductors such as Cuprates. Very high local E-fields within patches also suggest possibility that some sort of proximity effects might be induced locally in substrate material located beneath

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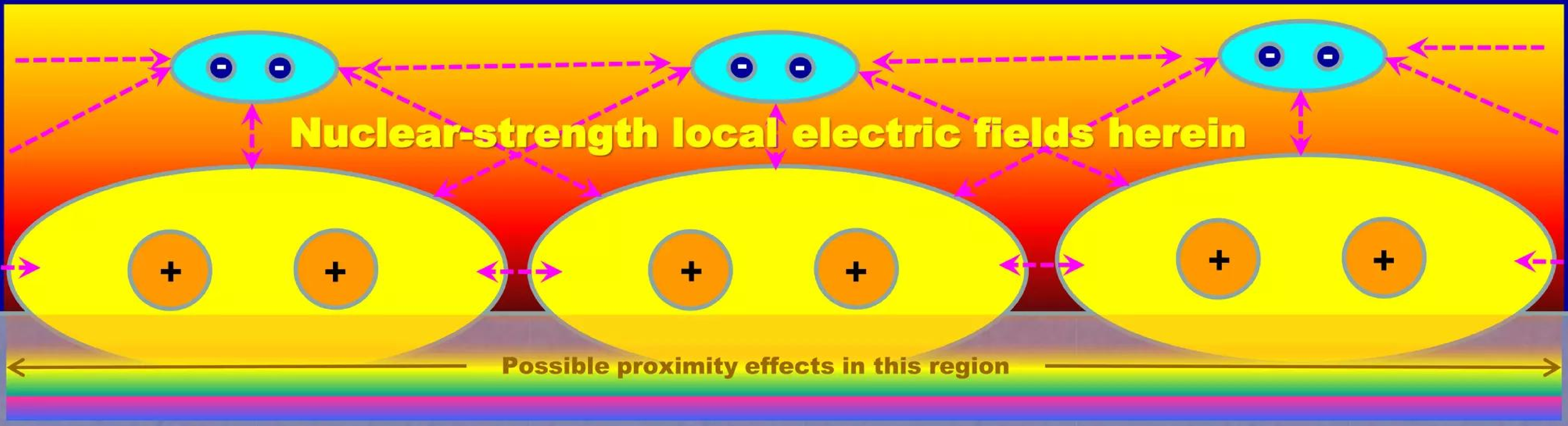
Speculate: create Cooper pairs of protons and SP electrons?

Do electromagnetically interacting 2-D mirror quantum condensates form in surface heavy-electron patches prior to their going nuclear?

Conceptual overview of condensates within a given many-body patch

What might be facilitating the formation of Cooper pairs in patch quantum condensates?



Substrate: in this example, it is a hydride-forming metal, e.g. Palladium (Pd); however, it could just as easily be an Oxide (in that case, SP electrons would be present at interface between patches and substrate, not across the entire substrate surface as would be the case if the underlying substrate was a metal)

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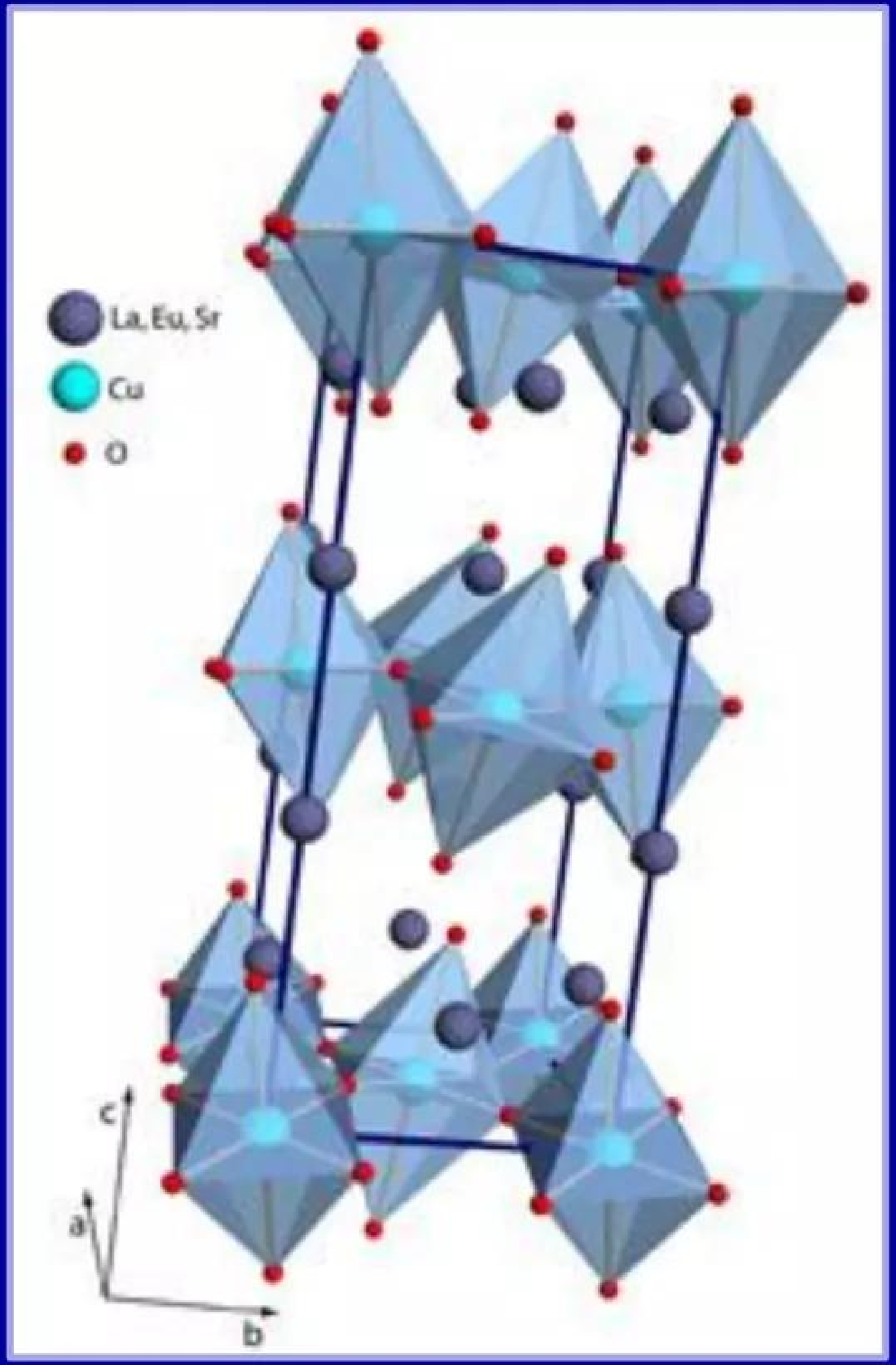
Quantum condensates and HTSC in W-L theory patches

Speculative discussion of theoretical ideas

- ✓ **If a type of evanescent HTSC truly occurs in PdHx W-L patches, it may be helpful to first discuss what it is not likely to be:**
  - **Type-I classic BCS - substrate lattice phonons would not appear to be involved in electron-pairing quantum condensate formation process that would necessarily have to occur in the SP electron subsystem, since those electrons are coupled more strongly to the dynamics of the intervening, locally dominant proton subsystem (thanks to breakdown of Born-Oppenheimer approximation in patches)**
- ✓ **If not Type-I, the next potential alternative is that we could perhaps be dealing with some new variant of known Type-II superconductors. Well, there are both pluses and minuses with that particular conceptualization as follows:**
  - **Pluses - patch HT superconductivity, if present, would likely be an in-plane ~2-D phenomenon which would be broad-brush conceptually consistent with known Type-II behavior; if Tripodi et *al.'s* experimental measurements are ultimately shown to be correct, there would be little doubt that RTSC is physically possible, at least in some types of systems; Lipson's *ca*. 2005 experimental observations are broadly consistent with low temperature Type-II behavior in PdHx; both Tripodi and Lipson *et al.* experimentally observed the Meissner effect**
  - **Minuses - a widely accepted, detailed theory of Type-II superconductivity is not yet available; except for Tripodi's work and that of a handful of other researchers, there still isn't any widely accepted experimental evidence for superconductivity occurring at anywhere close to room temperature (RTSC), let alone well above it; protons have not previously been known to participate in superconductivity (except in theoretical work involving cores of neutron stars); lastly, except for a hint in Lipson's work, oxides do not appear to play a major direct role in W-L patches, which is decidedly unlike the vast majority of known oxide-based HTSCs**



Source: *"*Light induced Superconductivity in a Stripe-ordered Cuprate,*"* A. Dienst *et al.*, *Science* 331 pp. 189-191 (2011) - "Structure of a $LaEuSrCuO_4$ crystal (positions of La, Eu, Sr are not distinguishable). CuO_4 builds connected tilted octahedral structures."

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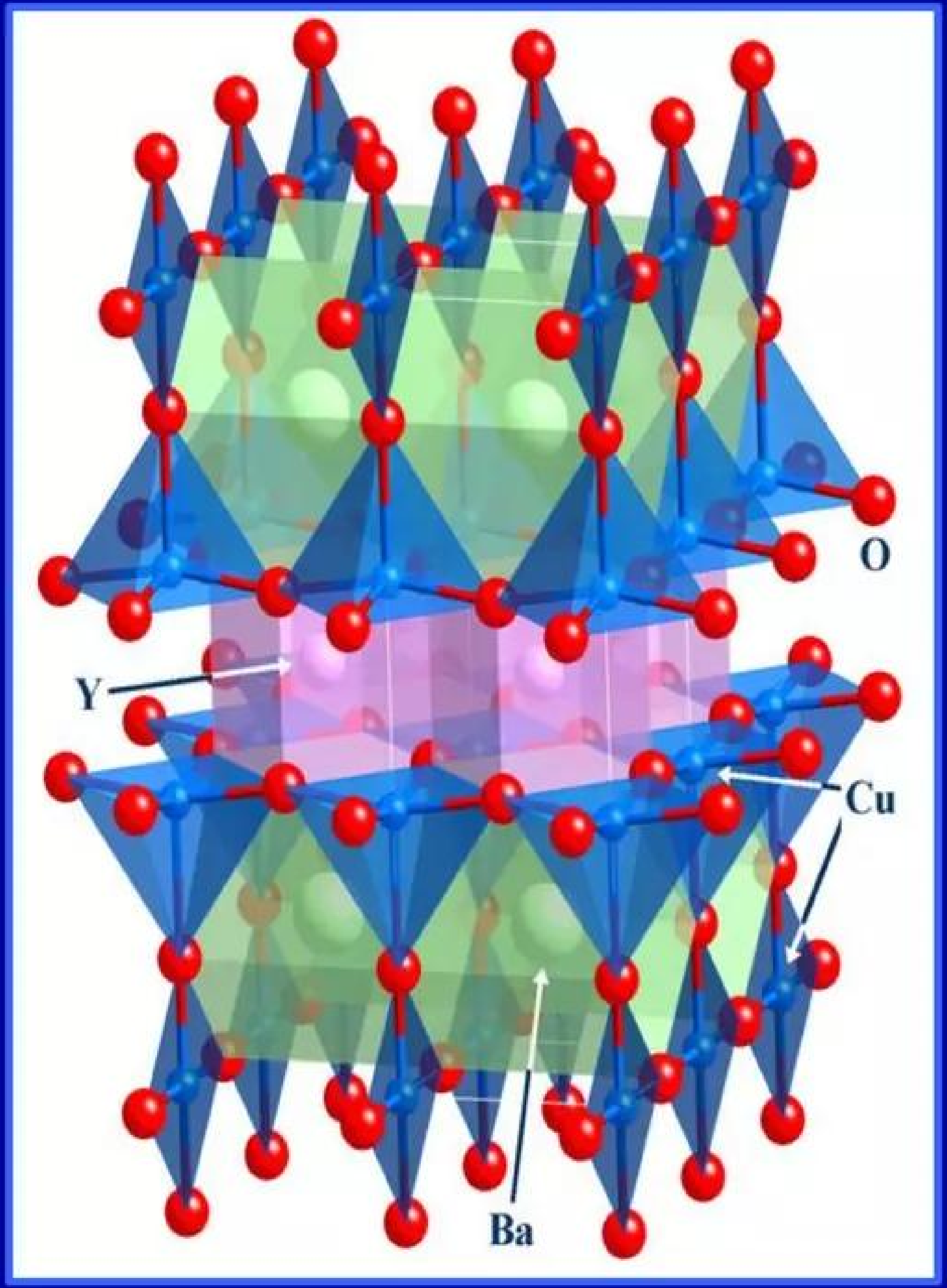
Quantum condensates and HTSC in W-L theory patches

Speculative discussion of theoretical ideas

- ✓ **Protons are fascinating entities - in the context of W-L patches, they can be viewed as simply being entangled hydrogen atoms or as entangled nucleons (*p*+). That being the case, there may be some utility in conceptualizing such patches as being akin to exotic, very large, pancake-shaped, short-lived quasi 'atoms' that, instead of being a many-body collection of nucleons confined and held together mainly by the strong force, are confined and held together mostly by a complex combination of chemical bonds, local electromagnetic fields, and many-body collective quantum effects; i.e., like a quantum dot on steroids; unclear exactly what this radical thinking might mean**

- ✓ **Analogy exists between W-L patches and quantum dots - in patches, heavy-mass SP electrons can directly convert locally produced gamma radiation into infrared photons (with a poorly understood, variable emission tail in soft X-rays) at high efficiencies. This process is explained in a 2005 arXiv preprint, "Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces," and fundamental US patent issued to Lattice in 2011, US 7,893,414 B2. Interestingly, it turns-out that there is a close analogue for this type of photon energy down-conversion that also occurs in quantum dots and is called, "luminescent downshifting"; please see:**
  - **"Performance of Hydrogenated a-Si:H solar cells with downshifting coating" B. Nemeth *et al.* (preprint) Conference Paper NREL/CP-5200-51824 (May 2011) http://www.nrel.gov/docs/fy11osti/51824.pdf**

- ✓ **Micron-scale delocalization of electron, proton, and neutron Q-M wave functions – apart from the seminal experimental work of Chatzidimitriou-Dreismann *et al.,* the experimentally verified fact (Cirillo *et al.* 2012) that ultra low momentum (ultra-long Q-M wavelength) delocalized band-state neutrons are produced via collective electroweak reactions in W-L patches implies that the same degree of delocalization must be true for protons present in a patch and likely also for SP electrons. This argues in favor of idea that evanescent HTSC might be occurring in such patches**



Source: Wikipedia - $YBa_2Cu_3O_7$: A hybrid ball and stick/polyhedral representation of the $YBa_2Cu_3O_7$ structure http://commons.wikimedia.org/wiki/File:YBa2Cu3O7.png

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- ✓ **Formation of Cooper pairs in quantum condensates – while it is not terribly difficult to imagine creation of Cooper pairs of entangled electrons in an SP electron patch subsystem, the issue of comparable pairing for protons is somewhat unfamiliar - more problematic. Like electrons, the problem with Coulomb repulsion between protons is obvious. That being the case, viewing the proton patch subsystem as a quantum plasma, is there an attractive force between protons that might plausibly facilitate the formation of bosonic Cooper pairs in a W-L patch? It turns-out that there may well be such a force; please see:**

  - **"Novel attractive force between ions in quantum plasmas"**
    P. Shukla and B. Eliasson
    ***Physical Review Letters* 108 pp. 165007 - 165012 (2012)**
    http://arxiv.org/pdf/1112.5556v7.pdf

- ✓ **Alternatively, could electron and/or proton spin density waves perhaps also help create quantum condensates in patches? – in a recent presentation, "Quantum phases of matter" (2012), Subir Sachdev (Harvard) described a theoretical mechanism for recently discovered group of Iron-based superconductors, e.g., $BaFe_2(As_{1-x}P_x)_2$, in which the attractive force between electrons (which enables formation of Cooper pairs) is presently thought to arise not from their interactions with lattice phonons, but rather from a so-called "spin density wave" (SDW) that spatially organizes up/down electron spin configurations at lattice sites. Interestingly, when the net antiferromagnetic moment (*m*) measured across the entire lattice vanishes as $x = x_c$ (i.e., at the quantum critical point), the electrons involved are all effectively entangled and must be treated as a many-body quantum subsystem**

Let us imagine a W-L patch proton subsystem as a dynamically organized 'lattice' of sorts, perhaps something akin to so-called "Coulomb crystals" that arise and are experimentally well-known in dusty, non-ideal plasmas. If that were the case, and since both electrons and protons assuredly possess spin, by analogy perhaps something like a SDW could also help enable the formation of electron and/or proton Cooper pairs in a W-L patch?

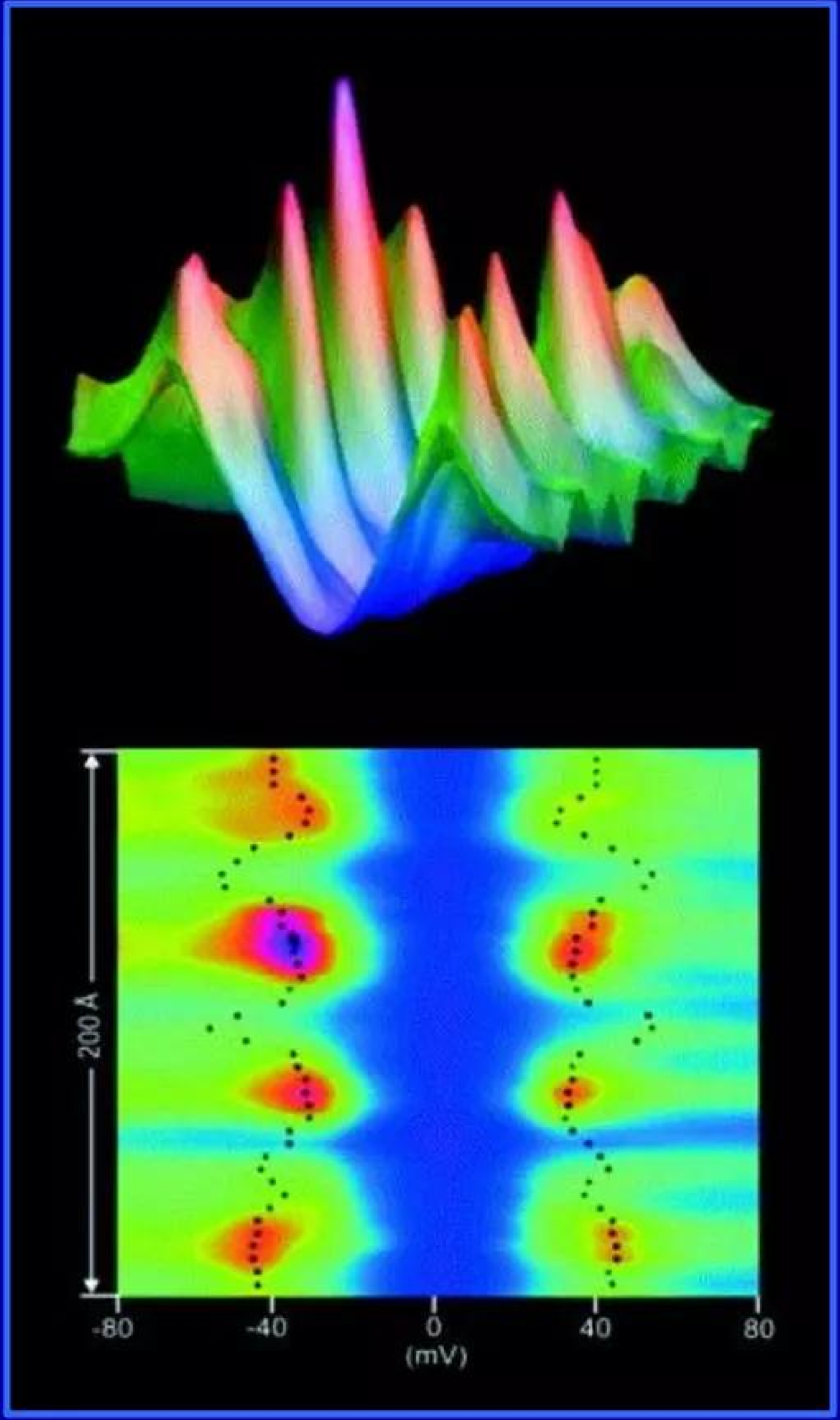

Fig. 18. 2D (bottom) and 3D (top) plots of the spatial dependence of the differential conductance showing the microscopic inhomogeneity in magnitude of superconducting gap in $Bi_2Sr_2CaCu_2O_{8-x}$ in E. Plummer *et al.* *Surface Science* 500 pp. 1-27 (2002)

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Quantum condensates and HTSC in W-L theory patches

Speculative discussion of theoretical ideas

- For this discussion please see following references:
  - *"Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces"*
    A. Widom and L. Larsen (2005) [see Slide #2 for full reference and hyperlink]
  - "Room temperature superconductivity"
    A. Mourachkine [author placed copy of entire 310-page book on arXiv]
    Cambridge International Science Publishing (2004)
    http://arxiv.org/ftp/cond-mat/papers/0606/0606187.pdf

- In evanescent W-L patches, both the proton and SP electron subsystems are characterized by strongly correlated, entangled particles and long-range Q-M coherence up to the physical dimensions of a given patch, which can range from several nm up to perhaps as large as ~100 microns

- Apart from having nuclear-strength local electric fields, what is extremely unusual about W-L patches are the energy-scales present therein. In typical condensed matter environments and superconductors at chemical energies, meVs and eVs are the norm. By contrast, in energized patches, intrinsic energy scales of particles therein can range from eVs to keVs --- up to MeVs, i.e., they can and do enter the nuclear energy realm, unlike everyday lattice environments

- Quoting excerpts from our 2005 arXiv preprint: "In order to achieve heavy electron pair energies of several MeV … The energy differences between electron states in the heavy electron conduction states is sufficient to pick up the 'particle-hole' energies of the order of MeV. Such particle-hole pair production in conduction states of metals is in conventional condensed matter physics described by electrical conductivity … energy spread of heavy electron-hole pair excitations implies that a high conductivity near the surface can persist well into the MeV photon energy range, strongly absorbing prompt gamma radiation … energy spread of the excited particle hole pair will have a cutoff of about 10 MeV based on mass renormalization of … the electron"

- While no direct experimental measurements of energy spreads in W-L patches have ever been made, one could speculate that they might well be much larger than those of presently well-known Types 1-2 superconductors. If mirror Cooper pairs of SP electrons and protons can form in a coherent W-L patch, perhaps it is not unreasonable to expect that pairing energies therein might exceed value of 150 meV Mourachkine (2004) calculated for a RTSC at 580 K

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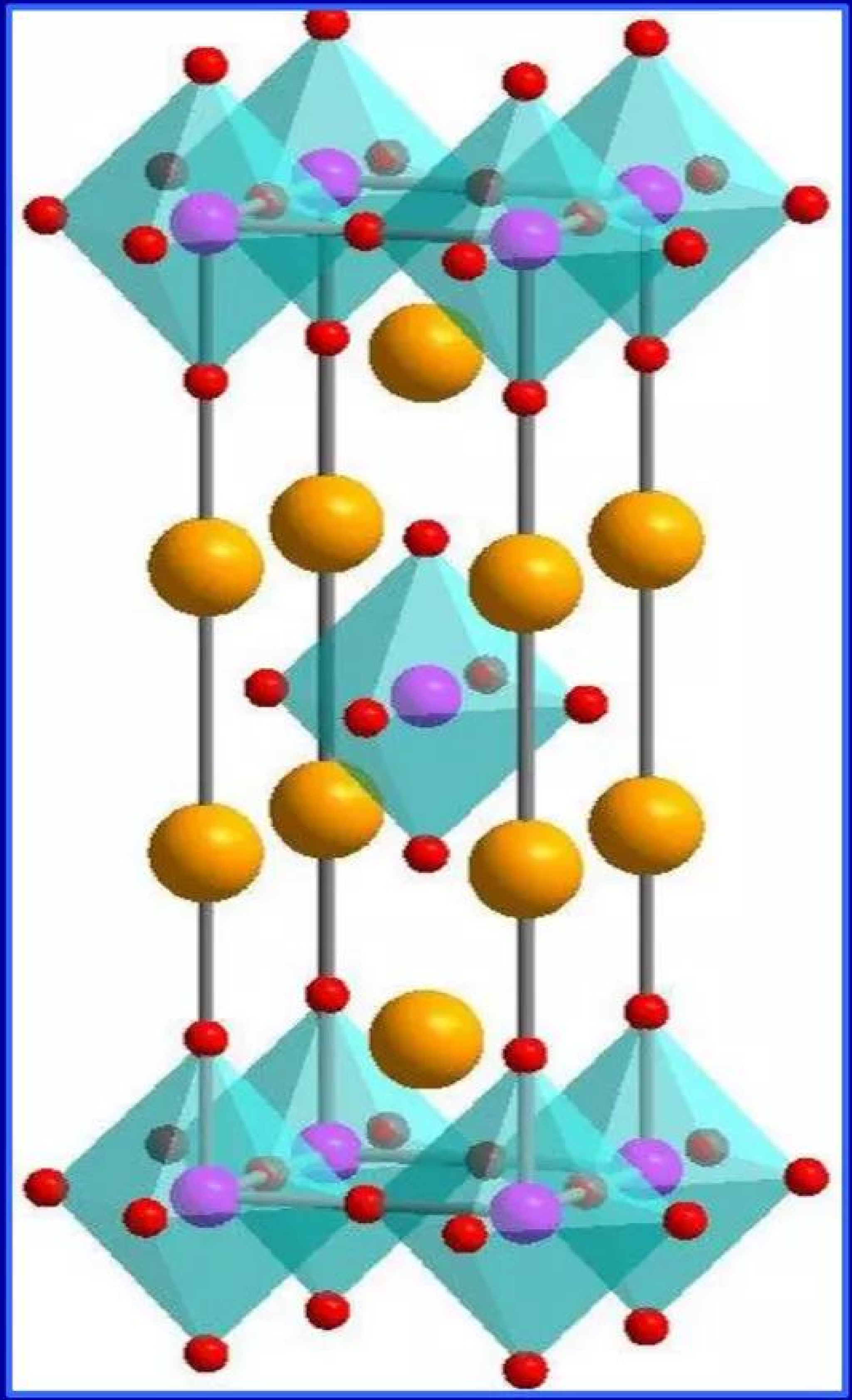
Quantum condensates and HTSC in W-L theory patches

Wrap-up on speculative discussion of theoretical ideas

Summary:

- ✓ Certain experimental data suggests that some form of HTSC may be occurring in W-L many-body patches found in LENR systems
- ✓ While not widely known or accepted, controversial experimental data collected and published by Tripodi *et al.,* if correct, suggests that >RTSC might be possible, at least in PdH_x superconducting systems
- ✓ If HTSC or RTSC truly does occur in W-L heavy-electron patches, although it shares some common characteristics with Type-2 superconductors, it differs significantly in many key ways
- ✓ For example, normal lattice electron-phonon interactions seem unlikely to be involved in facilitating formation of Cooper pairing in a W-L patch's SP electron subsystem. Instead, it seems like, during brief attoseconds of collective proton coherence, the many-body collective proton subsystem somehow functions as a local 'lattice' (*a la* a dynamic Coulomb crystal???). Viewed in that manner, a many-body proton subsystem's electromagnetic and Q-M interactions with a patch's many-body SP electron subsystem might then be able to provide a local environment conducive to SP electron pairing therein. Perhaps a patch's two subsystems form dynamic, mutually reinforcing mirror quantum condensates' as conceptualized on Slide #81 herein
- ✓ Hopefully, subject matter experts will study these new theoretical ideas to see whether they might lead to additional fruitful insights



Credit: Y. Liu (Penn State Univ.)
p-wave superconductor Sr_2RuO_4

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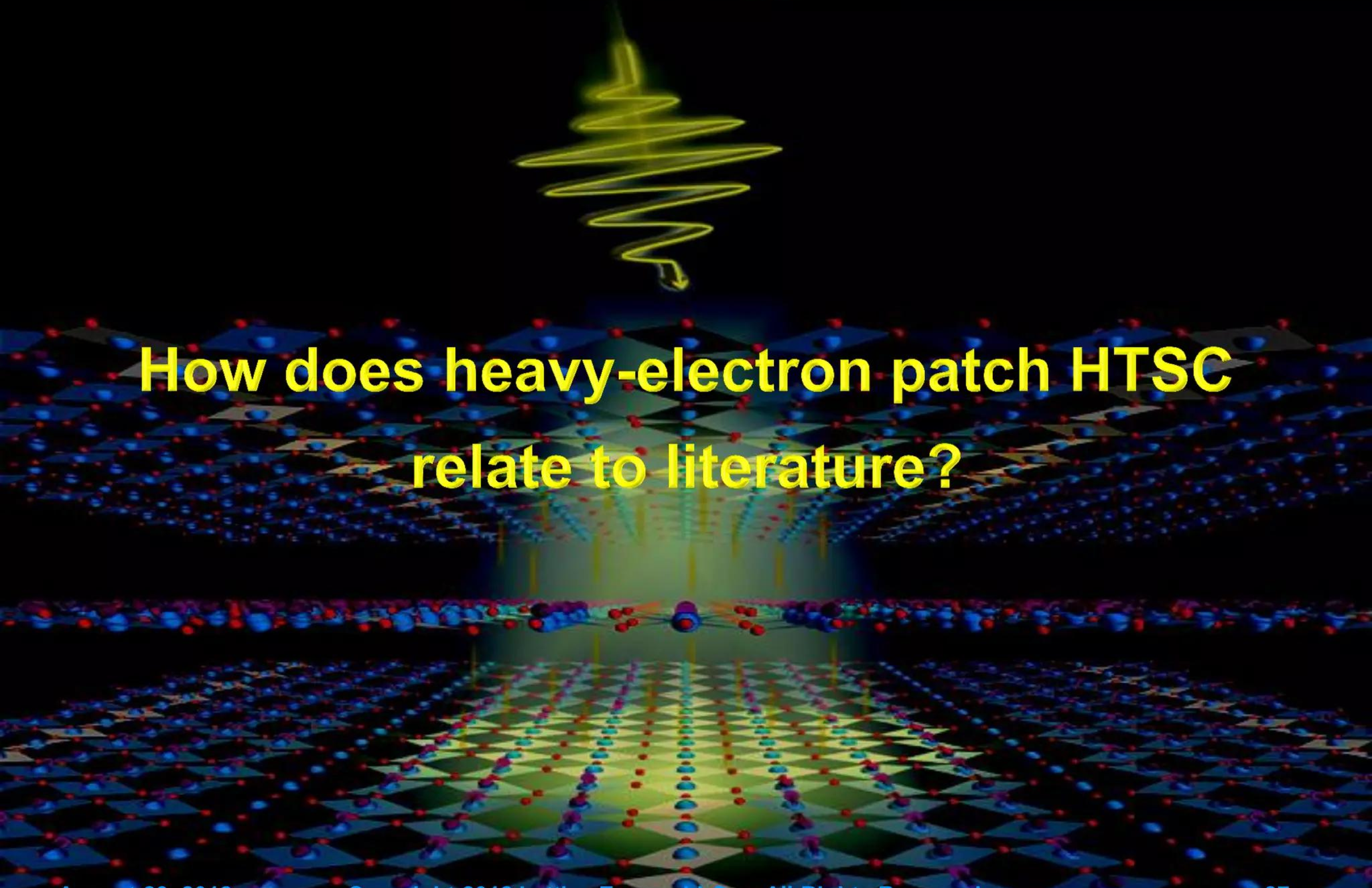

How does heavy-electron patch HTSC relate to literature?

How does heavy-electron patch HTSC relate to literature?

While somewhat like Type-2, heavy-electron HTSC differs in key aspects

- ✓ Apart from reading a large number of published papers, some of which are cited herein, two must-read references shown to the right were particularly helpful to the author, who is not an expert on HTSC
- ✓ As noted earlier, if some form of HTSC or maybe even RTSC is truly occurring in W-L heavy SP electron patches, it may be providing us with some new and interesting theoretical twists on HT superconductivity along with daunting experimental challenges that must be surmounted to fully understand what might be happening in these nanoscale many-body quantum systems
- ✓ As promised, this presentation raises many more questions than it answers. Hopefully, it will help provide impetus for additional theoretical and experimental work by other researchers

→ "Strange and stringy"
S. Sachdev, Harvard University
Scientific American (October 2012)
http://qpt.physics.harvard.edu/c63.pdf

Abstract (quoted from an earlier preprint):

"In many modern materials, 10^{23} electrons quantum-entangle with each other, and produce new phases of matter, such as high temperature superconductors. The challenge of describing the entanglement of such a large number of electrons may be met by ideas drawn from string theory."

→ "Room temperature superconductivity"
A. Mourachkine
Cambridge International Science Publishing (2004)
http://arxiv.org/ftp/cond-mat/papers/0606/0606187.pdf

Future technological opportunities: heavy-electron RTSC

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Future commercial opportunities: heavy-electron RTSC

Key technological hurdle: take SC effect from evanescent to persistent

- ✓ If some form of HTSC is truly occurring in W-L theory collective many-body heavy electron patches, its unique characteristics might provide an attractive R&D path toward developing a viable commercial room temperature superconductor technology
- ✓ Unfortunately, at the moment W-L patches are evanescent structures that have relatively short <400 ns lifetimes because once they make ultra low momentum neutrons and go hot-nuclear they effectively destroy themselves, which locally wipes-out any HT superconductivity that might be previously present
- ✓ However, there could potentially be a technological workaround for this problem: imagine designing and fabricating a superconducting device in which local nanoscale electric field strengths can be tightly controlled and persistently clamped at values that are maintained just a little below thresholds where neutrons are produced, i.e., the hot-nuclear LENR regime is effectively suppressed across the surface
- ✓ Further imagine, just for the sake of having a concrete example, that our hypothetical device consists of a graphene ribbon decorated with specially engineered, conductive nanoparticles that can effectively clamp surface electric fields within key design specifications, thus enabling what functions effectively as a wire-like structure that can operate as current-carrying superconductor at temperatures up to 580 K
- ✓ Realistically, it may not necessarily be easy to successfully engineer such a system and insure that that it is competitive and cost-effective. However, if that goal were achieved, there is little doubt that it would likely be a valuable technology suitable for use in number of important commercial market applications
- ✓ Obviously, this document does not reveal everything Lattice knows about this subject. We would be interested in partnering or consulting with large, established companies that would have a strong mutual interest in further pursuing this unexpected offshoot of our ongoing work in LENR technology

Final quotations

"Tight-lipped, guided by reasons only,
cautiously let us step into the era
of the unchained fire."

Czeslaw Milosz, poem "Child of Europe," New York, 1946

Interdisciplinary effort needed to unravel HTSCs in LENRs

"A scientist is supposed to have a complete and thorough knowledge, at first hand, of some subjects and, therefore, is usually expected not to write on any topic of which he is not a master. This is regarded as a matter of noblesse oblige. For the present purpose I beg to renounce the noblesse, if any, and to be freed of the ensuing obligation. My excuse is as follows: we have inherited from our forefathers the keen longing for unified, all-embracing knowledge. The very name given to the highest institutions of learning reminds us, that from antiquity and throughout many centuries the universal aspect has been the only one to be given full credit. But the spread, both in width and depth, of the multifarious branches of knowledge during the last hundred odd years has confronted us with a queer dilemma. We feel clearly that we are only now beginning to acquire reliable material for welding together the sum-total of all that is known into a whole; but, on the other hand, it has become next to impossible for a single mind fully to command more than a small specialized portion of it. I can see no other escape from this dilemma (lest our true aim be lost forever) than that some of us should venture to embark on a synthesis of facts and theories, albeit with second-hand and incomplete knowledge of some of them --- and at the risk of making fools of ourselves."

Erwin Schrödinger, "What is life*?*" (1944)

Image credit: Strano (MIT) - carbon nanotube rope, *Nature Materials*