Ultralow energy neutron reactions or LENRs

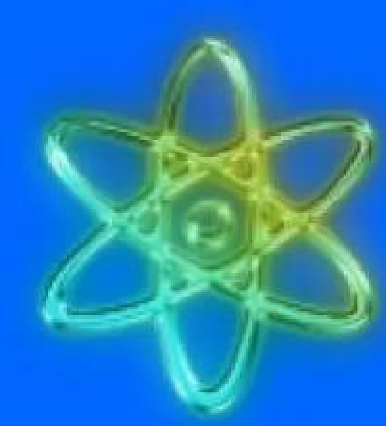
Widom-Larsen theory reveals surprising similarities to chemical catalysis

Japanese government NEDO-funded LENR device nanofabrication and testing project achieved 70 - 80% reproducibility for an average ~ 5 Watts excess heat for up to 45 days with ~ 100 gms bimetallic NPs

2018  NEDO  TRL-4

Project's experimental LENR device data resembles optimization of various bimetallic nanoparticle (NP) catalysts utilized in Hydrogen sensors, Hydrogen generation, and Suzuki-Miyaura C-C coupling reactions. This similarity was anticipated by Widom-Larsen theory of LENRs, which has unveiled striking parallels between chemical catalysis and many-body $e + p$ nuclear catalysis

Lewis Larsen
President and CEO
Lattice Energy LLC
November 4, 2018



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LENR technology's present global state of readiness = TRL-4

Participants in NEDO's LENR device nanofabrication and testing project

NEDO New Energy and Industrial Technology Development Organization

Combining the efforts of industry, government and academia and leveraging established international research networks. NEDO is committed to contributing to the resolution of energy and global environmental problems and enhancing Japan's industrial competitiveness.

NEDO

Research management company — Technova Inc. — Toyota controls the organization

MITSUBISHI | TOYOTA | NISSAN

TOHOKU UNIVERSITY | NAGOYA UNIVERSITY | KOBE UNIVERSITY | KYUSHU UNIVERSITY

Mitsubishi H.I.: very very deep experience in U^{235} nuclear fission reactor technology

Also designed and produces XASM-3 supersonic ramjet anti-ship missile

Toyota: world's 2[rd] largest automobile manufacturer; #1 in hybrid e-vehicles

Also doing 3G R&D in humanoid robots: latest is T-HR3 (like avatar of a human)

http://www.nedo.go.jp/english/

Lattice Energy LLC

LENRs are disruptive new source of safe, radiation-free nuclear energy

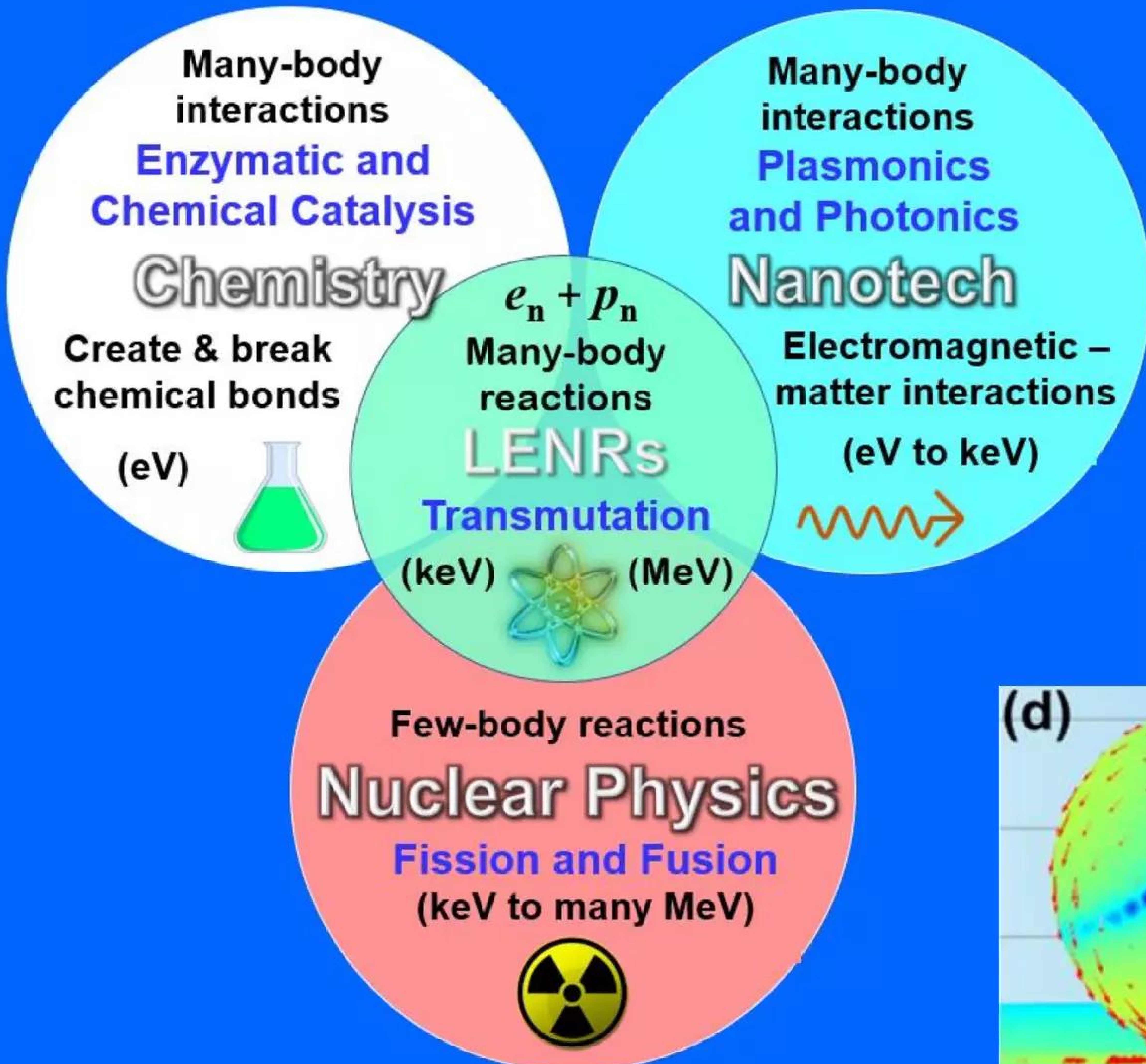
Japan, Inc. appears to be developing LENR technology for power generation to replace the internal combustion engine. Look at who is involved in NEDO LENR project.

Japan's beloved Mt. Fuji at dawn

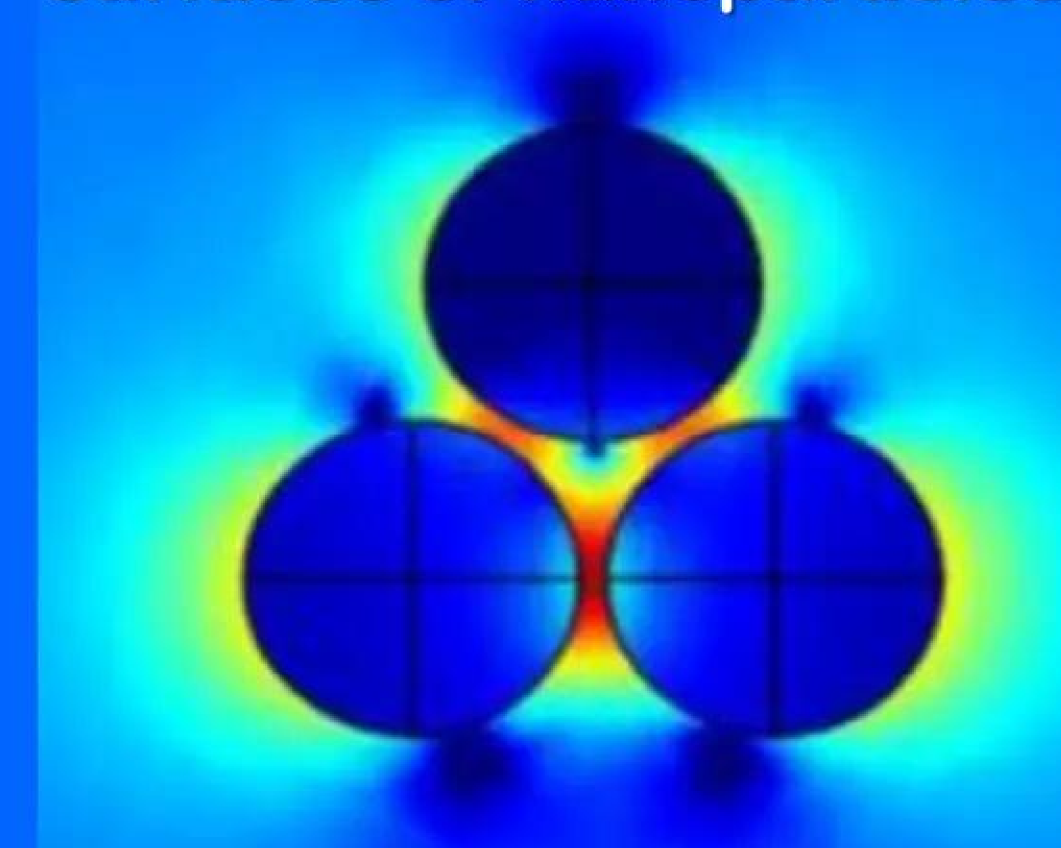
LENRs are not as exotic a technology as many might assume

Widom-Larsen theory: LENR physics, nanotech & chemistry interrelated

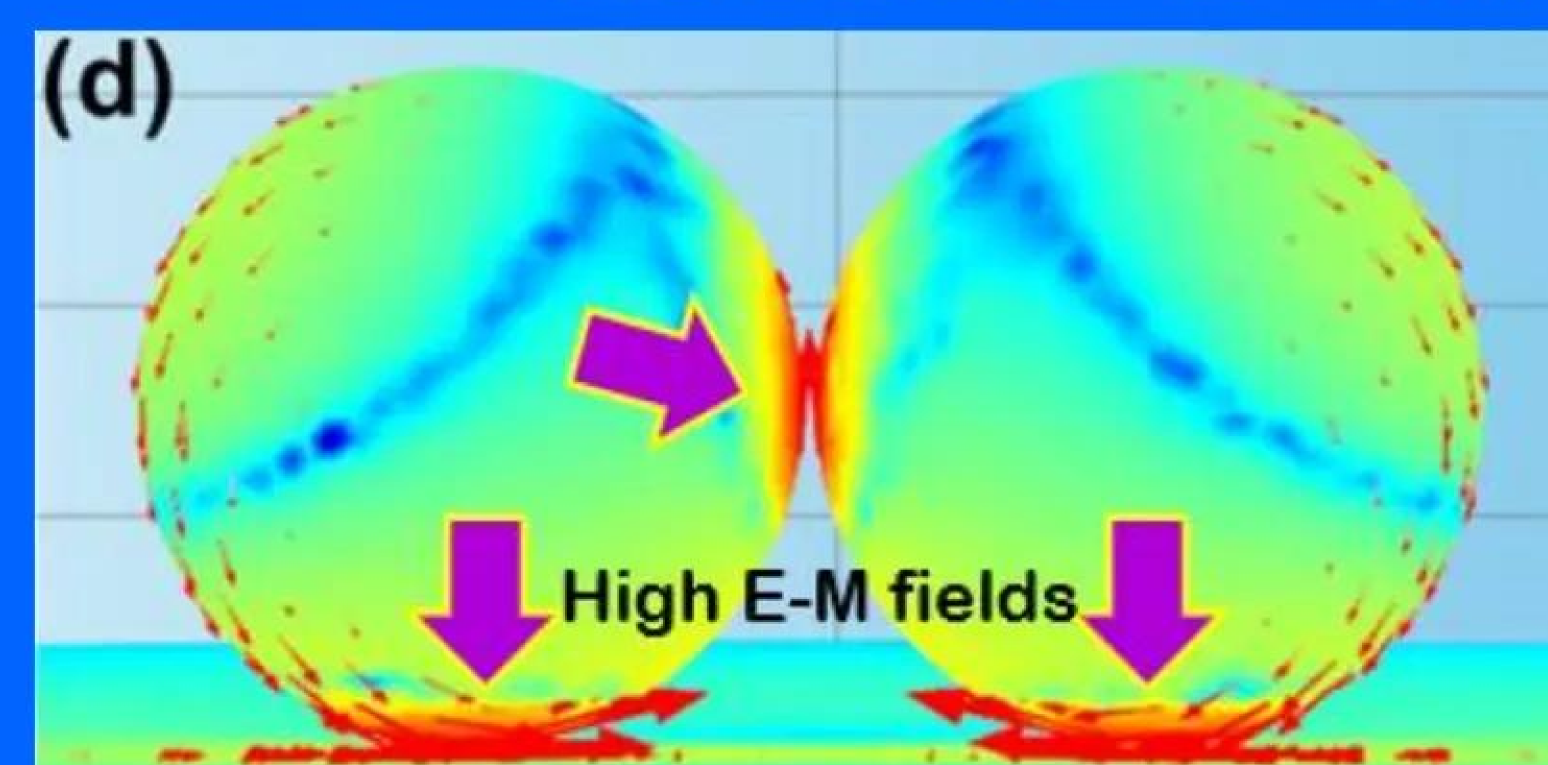
Leverage W-L theory & nanotech know-how to accelerate LENR development



Electric field strengths on surfaces of nanoparticles



$e_n + p_n$ reaction requires local E-fields > 10^{11} V/m



Electric fields >10^{10} V/m key to LENRs and chemical catalysis

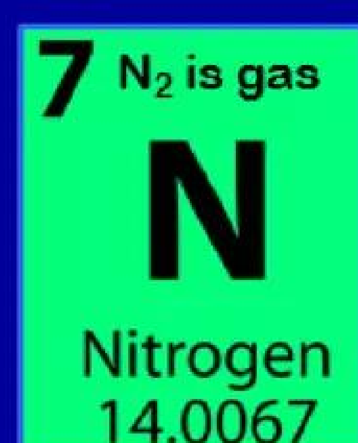
Japanese confirm importance of adsorbed protons and high local E-fields

Lattice Energy LLC

Survival of 40% of world's population crucially depends on higher food production enabled by Ammonia fertilizer produced in large plants via same Haber-Bosch process first commercialized by German company back in 1909

Progress being made with new catalyst technology that could potentially reduce capital and operating costs of future Ammonia plants which would be cost-effective in much smaller sizes that enable distributed production

Very high local electric fields ≥ 10^{10} V/m are key to vast increases in reaction rates for chemical catalysis, enzymatic catalysis, and electroweak nuclear catalysis (*e* + *p* reaction) in condensed matter



N_2 very inert

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June 27, 2017
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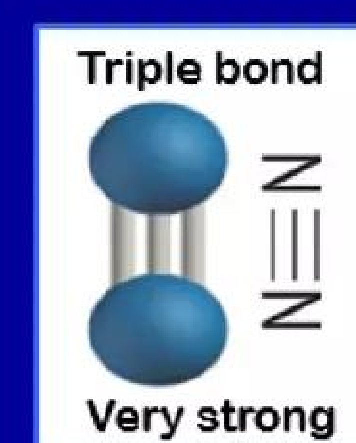


N_2 molecule

June 27, 2017 1

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-confirm-lattice-hypotheses-re-importance-of-adsorbed-protons-and-high-local-electric-fields-in-chemical-catalysis-june-27-2017

Nuclear and chemical reactions occur under same conditions

NEDO reactors triggered LENRs at 200 - 400^{o} C with bimetallic catalysts

Executive Technical Summary

Extensions of the Widom-Larsen theory of LENRs have for the first time revealed striking and unexpected similarities between electroweak nuclear catalysis --- collective many-body $e_n + p_n$ reaction in condensed matter --- and enzymatic catalysis, inorganic chemical catalysis, plasmon-mediated chemical photocatalysis with "hot" charge carriers, as well as widely published nanotechnology concept of heterometallic plasmonic antenna-reactor nanoparticles. Among numerous surprising commonalities between LENRs and chemical catalytic processes, many-body collective quantum effects and high local electric fields > 10^{10} V/m enable many chemical reactions and LENRs to proceed with substantial rates at vastly lower working temperatures and pressures. Existence of these parallels suggests that valuable new engineering insights can be obtained from certain aspects of nanotech and chemical catalysis and profitably applied to help accelerate future commercialization of LENRs for power generation.

Contents

Revolutionary LENRs could be used for power generation

Radiation-free LENRs transmute stable elements to other stable elements

Fission and fusion → Evolution of nuclear power → Safe green LENRs

Laura 13

No deadly MeV-energy gamma radiation

No dangerous energetic neutron radiation

Insignificant production of radioactive waste

Vastly higher energies vs. chemical processes

Revolutionary, no CO_2 , and environmentally green

Is fully explained by physics of Widom-Larsen theory

Image credit: co-author Domenico Pacifici
"Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng et al., *Nano Letters* pp. 602 - 609 (2012)

Key conclusions in *Pramana* W-L LENR theory review paper

Journal is peer-reviewed publication of Indian Academy of Sciences

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen in *Pramana* (2010)

"The analysis presented in this paper leads us to conclude that realistic possibilities exist for designing LENR devices capable of producing 'green energy', that is, production of excess heat at low cost without lethal nuclear waste, dangerous γ-rays or unwanted neutrons. The necessary tools and the essential theoretical know-how to manufacture such devices appear to be well within the reach of the technology available now. Vigorous efforts must now be made to develop such devices whose functionality requires all three interactions of the Standard Model acting in concert."

http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

W-L theory: LENR active sites convert gammas into infrared

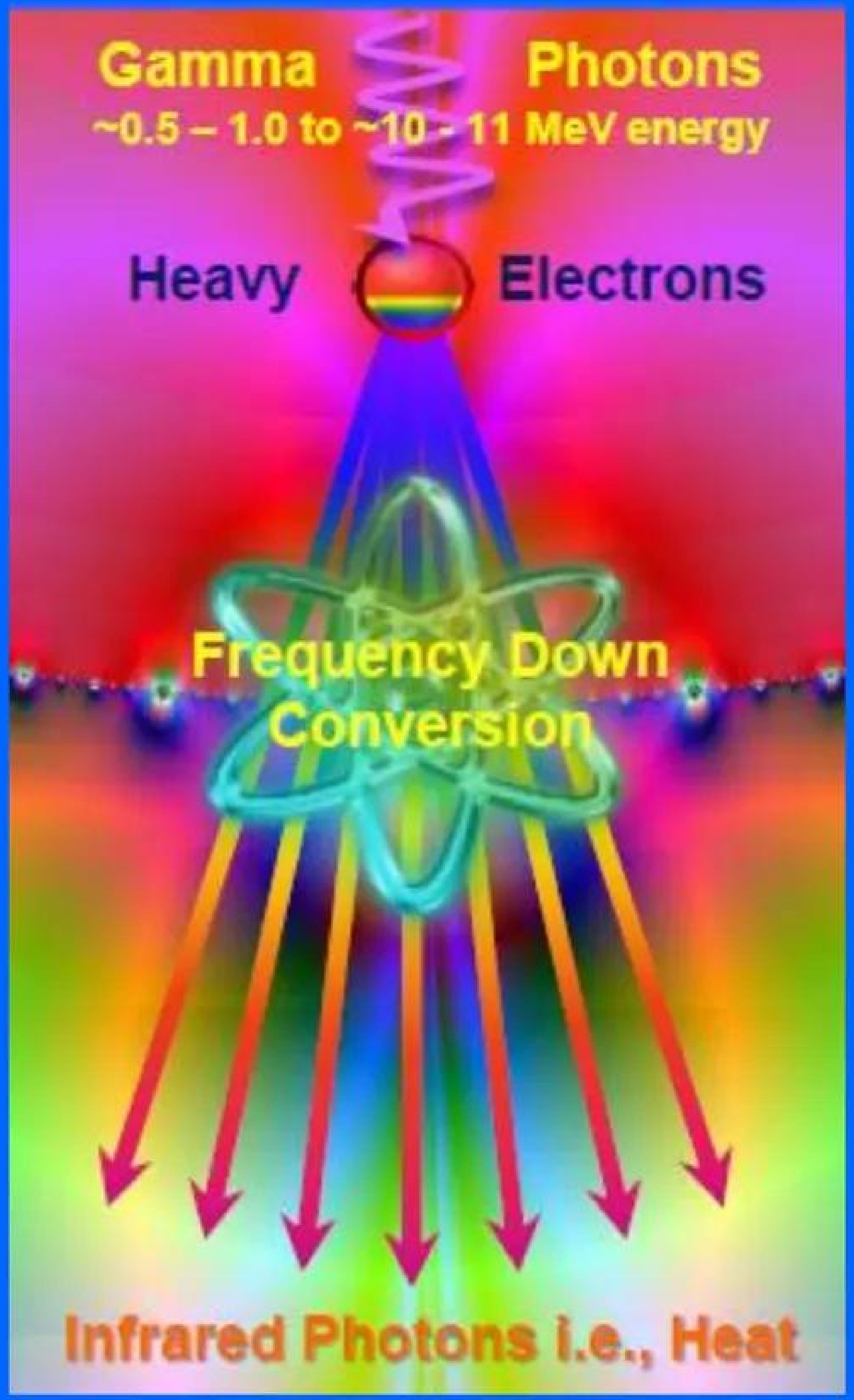
Key process is covered by Lattice's fundamental U.S. patent #7,893,414 B2

"Apparatus and method for absorption of incident gamma radiation and its conversion to outgoing radiation at less penetrating, lower energies and frequencies"

https://www.slideshare.net/lewisglarsen/us-patent-7893414-b2

Inventors: Lewis Larsen, Allan Widom
Issued: February 22, 2011
Assignee: Lattice Energy LLC

Unreacted heavy electrons naturally present in microscopic LENR active sites (in which ultralow energy neutrons are produced) will automatically and directly convert deadly MeV-energy gamma photon radiation produced locally by ULE neutron captures or nuclear decays into benign infrared (IR) photons (heat) that can be harvested to provide motive power or electricity. Absence of deadly energetic gamma and neutron radiation emissions from active sites enables LENRs to be safe and green, unlike nuclear fission and fusion processes



LENRs do not produce hard energetic radiation or radwastes

Absence of deadly radiation obviates need for shielding and containment

Enables future development of safe, battery-like, portable nuclear power sources

Today:
large Uranium fission power plants

Utility reactors require ~3 feet of concrete and ~1 foot of steel to shield humans from high-energy neutron & gamma radiation and highly radioactive wastes produced inside steel reactor vessel

Revolution in green nuclear technology

Future?
small systems

LENRs scale downward into small safe systems

Comparison of LENRs to fission and fusion reactions

Fission, fusion, and LENRs involve controlled release of nuclear binding energy (as heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; requires massive shielding and containment structures to handle radiation. Has major radioactive waste clean-up issues and costs. Limited choices of fuel today: almost entirely Uranium; Thorium-based fuel cycles now under development. Process: heavy element U-235 (fissile isotope fuel) + neutrons → complex mix of lower-mass fission products (some are very long-lived radioisotopes) + energetic gamma radiation + energetic neutron radiation + heat

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy. Present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) are focusing mainly on D+T fusion reaction which requires massive shielding and containment structures to handle 14 MeV neutron radiation. Minor radioactive waste clean-up $ costs vs. fission. Key fuels are Deuterium (D) and Tritium (T); both are heavy isotopes of Hydrogen). Commercial fusion reaction most likely to be first developed involves the following process:

D + T → He-4 (Helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): early-stage technology. Distinguishing features: neutron production via many-body collective $e + p$ reaction; no emission of energetic neutron or gamma radiation and no long-lived radioactive waste products. LENR systems would not require massive, expensive radiation shielding or containment structures → much lower $$$ cost. Many fuel choices --- any element/isotope that can capture neutrons. Process involves neutron-catalyzed transmutation of fuel into heavier stable elements; produces clean IR heat

Before 2006 $e + p$ thought to occur only in stellar explosions

Simple two-body reaction requires 10 billion degrees Kelvin inside stars

W-L theory: many-body collective quantum effects allow $e_n + p_n$ to occur on Earth

LENRs resemble enzymes in that temperature for $e_n + p_n$ reaction is radically decreased

Crab nebula: expanding gas cloud of huge supernova explosion of a star that was observed by many Chinese astronomers in 1054 A.D.

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen *EPJC* (2006)

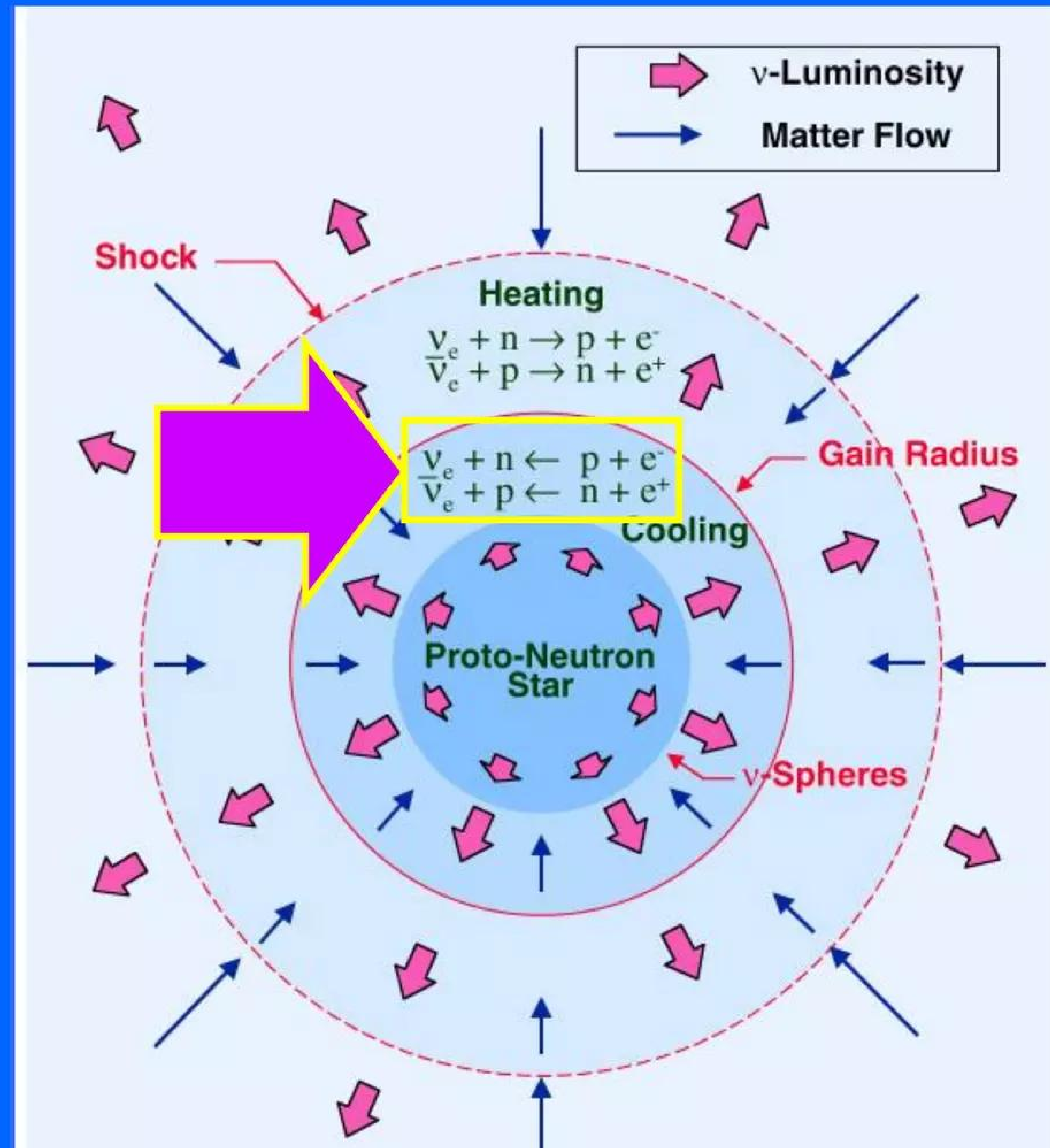


Image credit: TeraScale Supernova Initiative

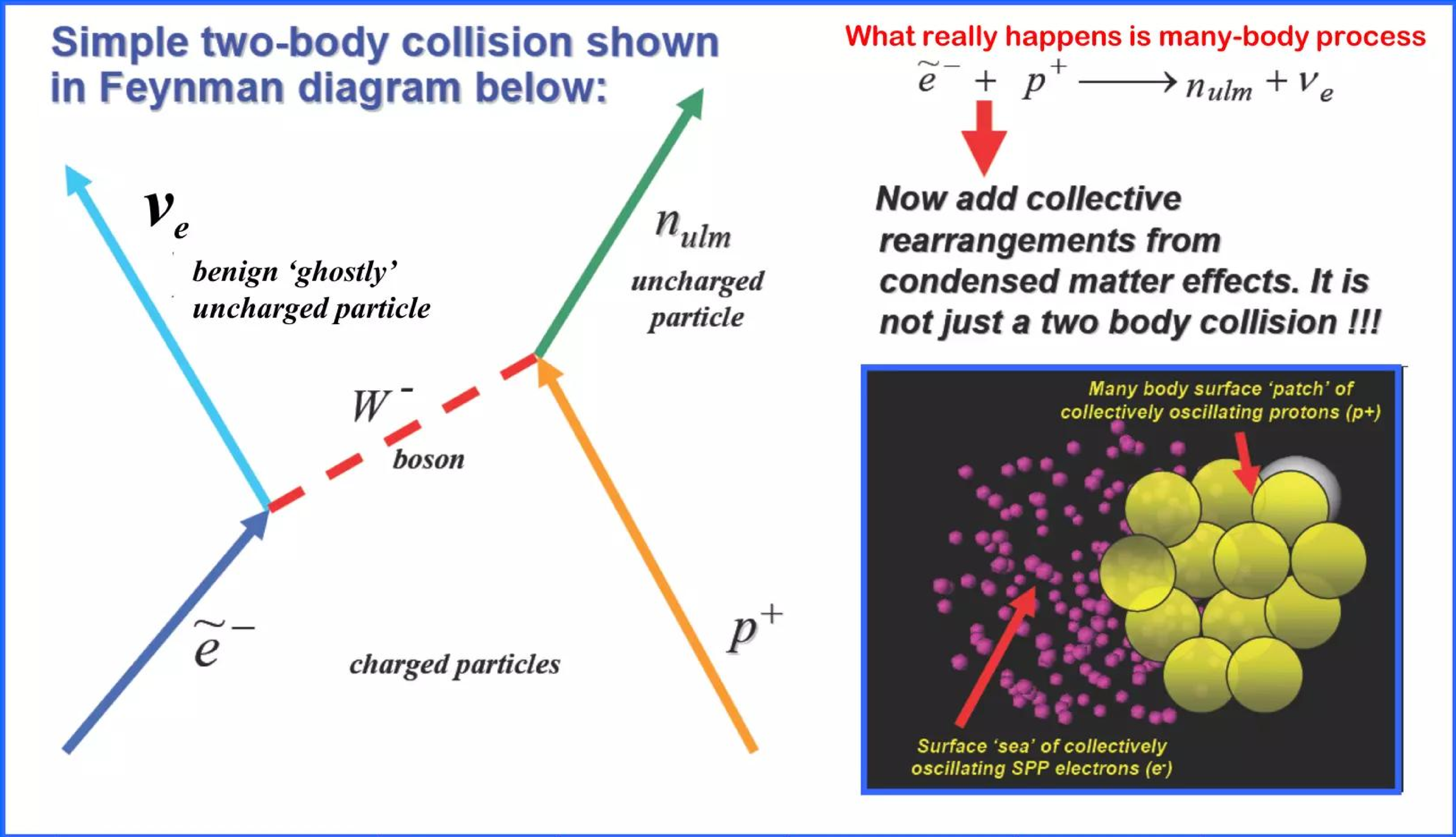
Many-body collective quantum effects are crucial to LENRs

Diagram is two-body $e^- + p^+$ reaction but what happens is many-body

Many-body collective effects involve mutual quantum entanglement

What actually occurs is a many-body reaction between entangled particles

LENR reaction is more accurately written as: $e_n + p_n \rightarrow n_{ule} + \nu_e$



Electroweak $e_n + p_n$ reaction per Widom-Larsen theory

Protons or deuterons react directly with electrons to make neutrons

W-L explains how many-body $e + p$ reactions can occur in condensed matter

Draw energy from electric fields > 10^{11} V/m

Heavy-mass e^{-*} electrons react directly with protons

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) → neutron and neutrino

$$\text{Energy}_{\text{E-field}} + e^-_{n\,sp} \rightarrow e^{-*}_{n\,sp} + p^+_n \rightarrow n^0 + \nu_e$$

ν_e neutrinos: ghostly unreactive particles that fly-off into space; n^0 neutrons capture on nearby atoms

Induces safe hard-radiation-free nuclear transmutation

Neutrons + atomic nuclei → heavier elements + decay products

Neutron capture $$n + (Z, A) \rightarrow (Z, A+1)$$

Beta decay $$(Z, A+1) \rightarrow (Z+1, A+1) + e_\beta^- + \bar{\nu}_e$$

Neutron capture-driven transmutation of isotopes and elements

Application of input energy is required to produce neutrons

Electron or ion currents; E-M photon fluxes; or organized magnetic fields

Input energy required to produce neutrons: 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 $e^{-*} + d^+ \rightarrow 2\ n$, $e^{-*} + t^+ \rightarrow 3\ n$ (energy cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can combine sources):

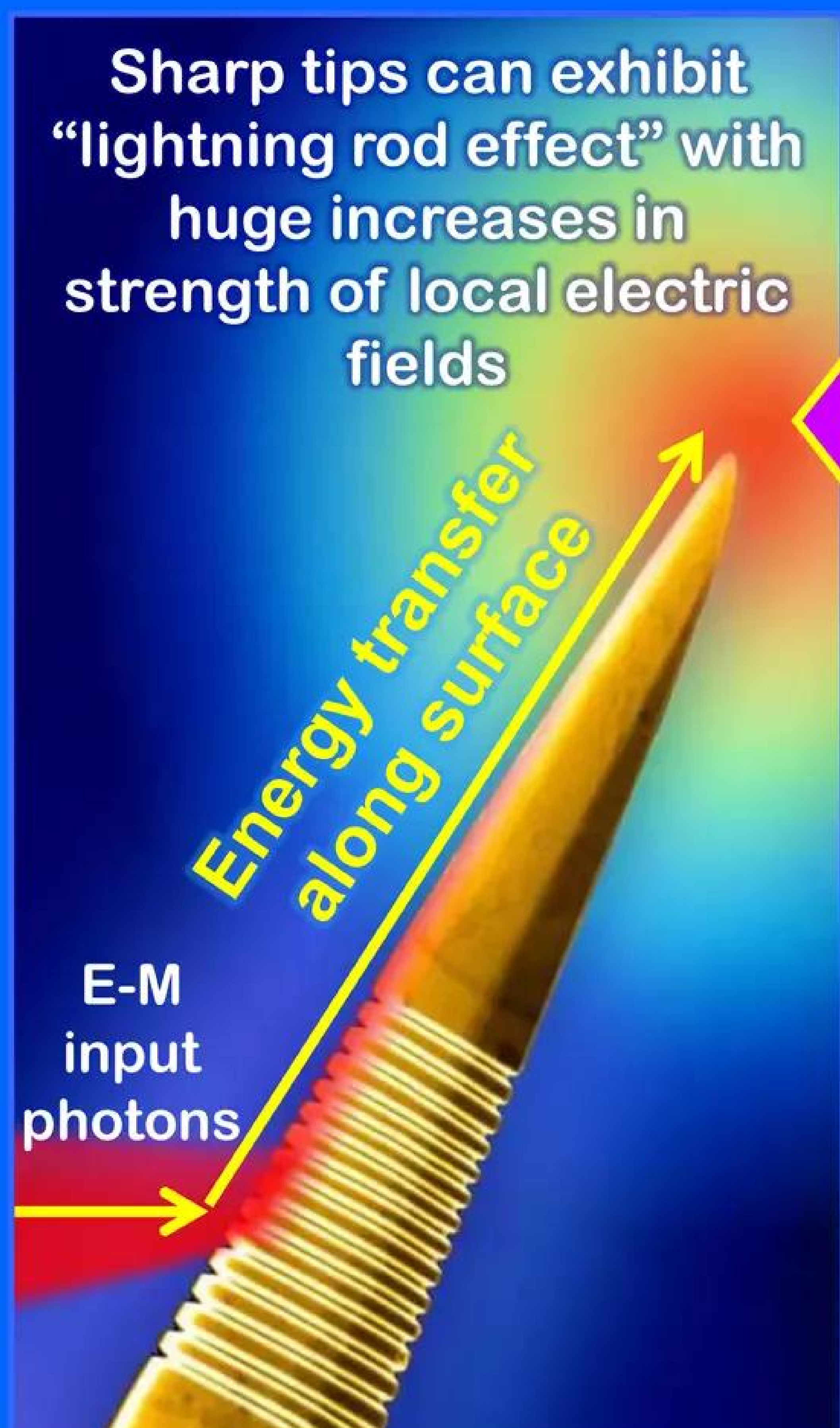
- Electrical currents - i.e., an electron 'beam' of one sort or another can serve as a source of input energy for producing neutrons via $e + p$ electroweak reaction
- Ion currents - passing across a surface or an interface where SP electrons reside (i.e., an ion beam that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used for inputting energy is a d^+ ion flux caused by imposing a modest 1 atm pressure gradient (Iwamura et al. 2002)
- Incoherent and coherent electromagnetic (E-M) photon fluxes - incoherent E-M radiation inside resonant electromagnetic cavities, e.g. NEDO project reactors; with proper momentum coupling, SP electrons can also be directly energized with coherent laser beams comprised of E-M photons at resonant wavelengths
- Organized magnetic fields with cylindrical geometries - many-body collective magnetic LENR regime with direct acceleration of particles operates at very high electron/proton currents; includes organized and so-called dusty plasmas; scales-up to stellar flux tubes on stars with dimensions measured in kilometers

Nanoparticles function as antennae that absorb E-M energy

Surface plasmons (SP) intensify local electric fields on nanoparticles

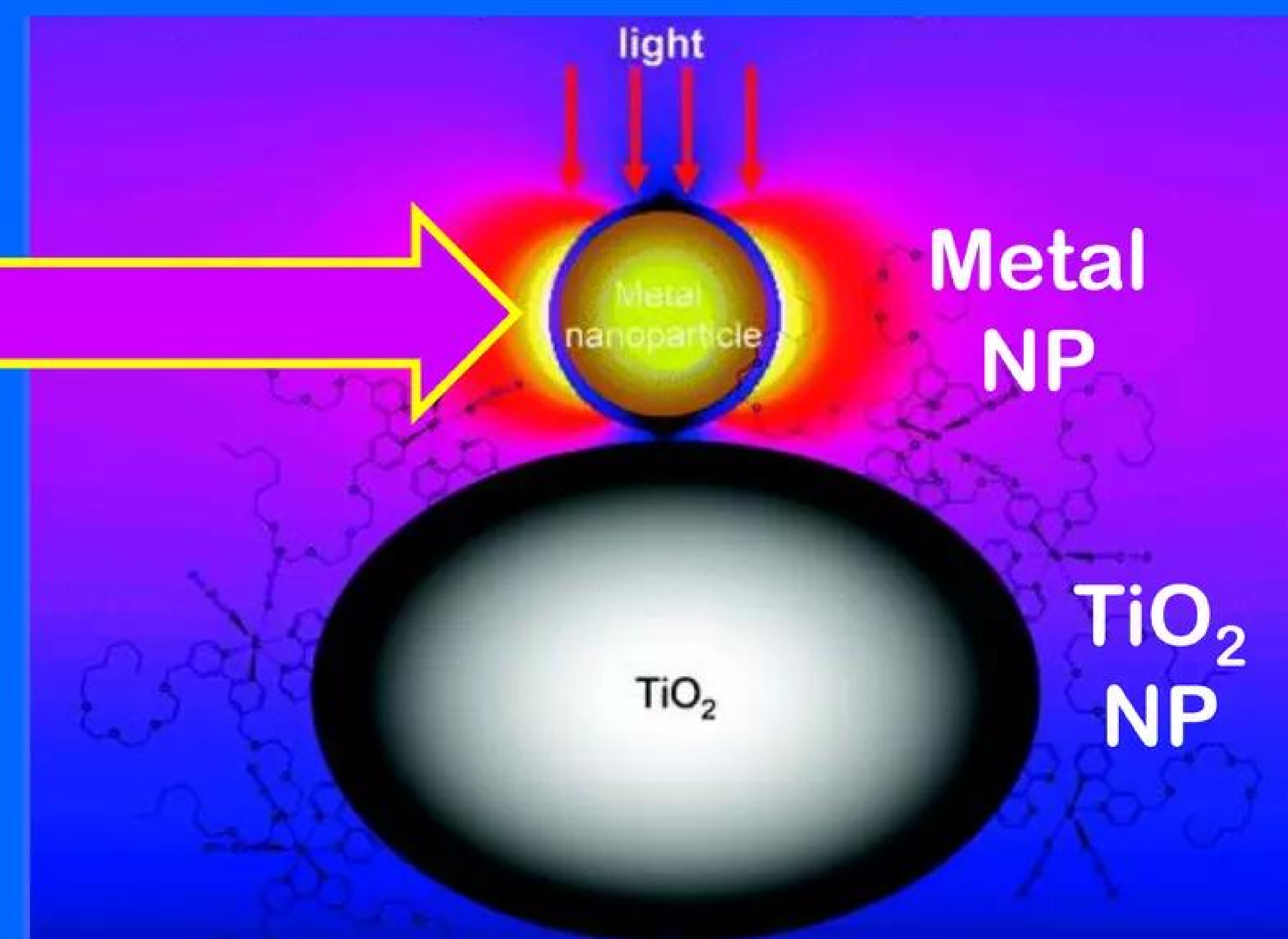
Nanostructures can be designed to create pulsed E-fields > 2.5 x 10^{11} V/m

Shows absorption of input E-M photons and energy transfer to LENR active sites via surface plasmon (SP) electrons



Regions of increased electric fields

Plasmonic light harvesting antennae



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

Source of above image is Wiesner Group at Cornell University: "Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles" M. Brown et al., *Nano Letters* 11 pp. 438 - 445 (2011)

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

Nanoparticle shapes/positioning can vastly increase E-fields

Fang & Huang's Figs.: input energy is concentrated in high electric fields

Properties can be predicted, modeled, and used to design active site precursors

Figure 1.

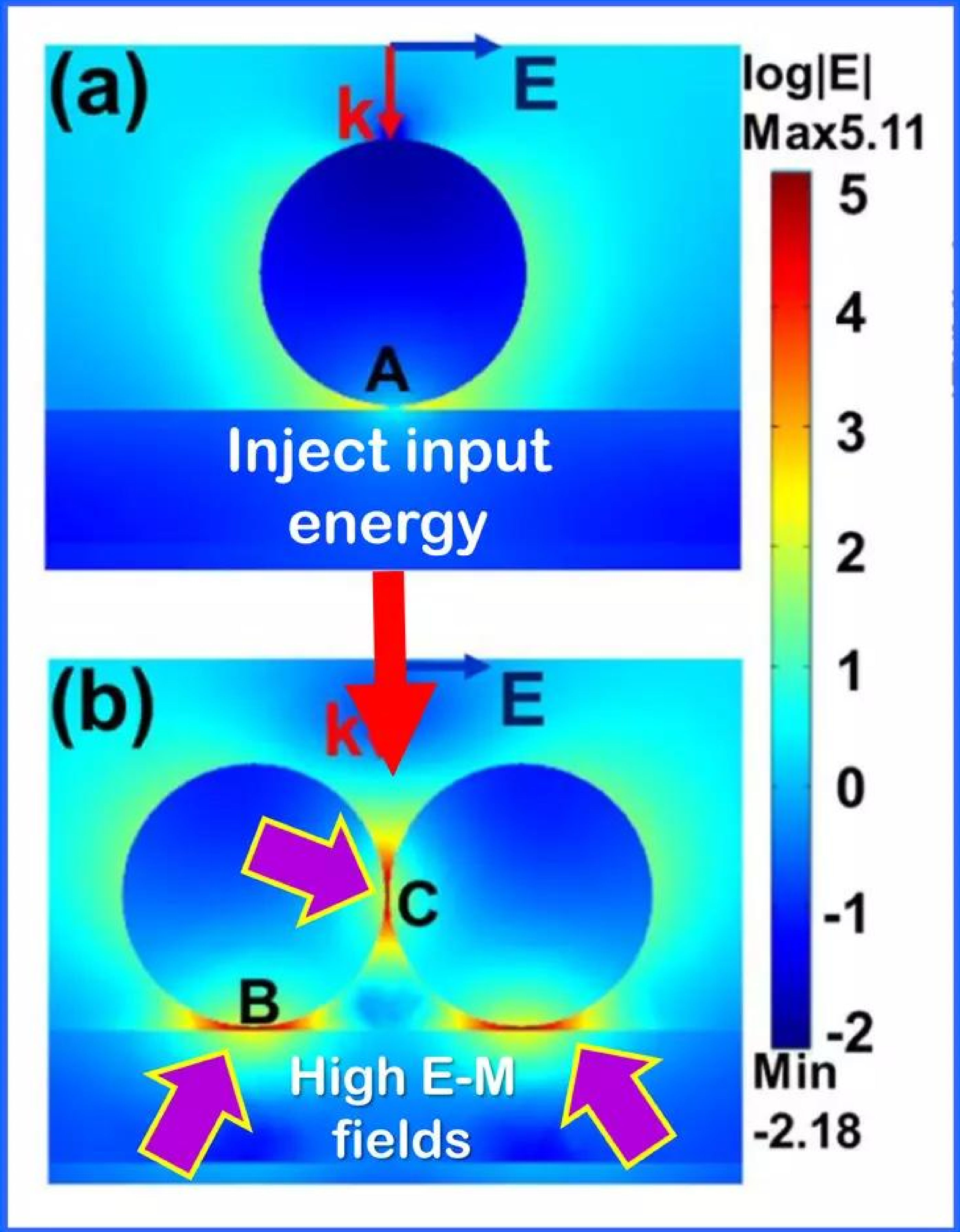
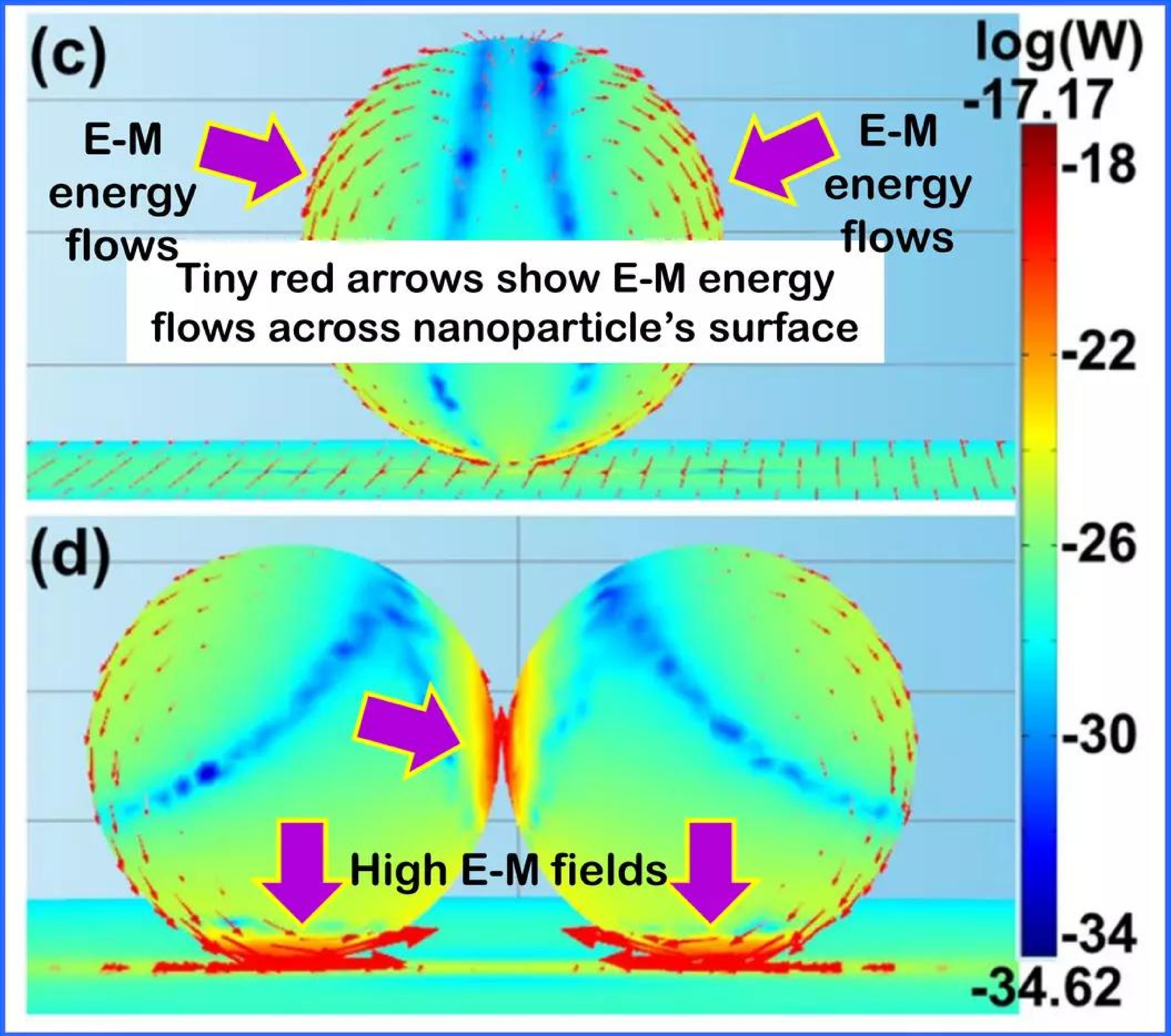


Figure 3.



http://publications.lib.chalmers.se/records/fulltext/178593/local_178593.pdf

Chemical and LENR processes actively coexist on surfaces

LENRs: complex interplay among E-M, chemical, and nuclear processes

Resonant E-M cavities can transfer E-M energy into LENR active surface sites

- Well-known that metallic and metal-oxide nanostructure surfaces and associated surface plasmon electrons can have configurations that will absorb electromagnetic (E-M) energy over a wide area, transport and greatly localize that energy, and --- in conjunction with contiguous surface 'patches' of Q-M entangled, collectively oscillating protons --- create nuclear-strength local electric fields > 2.5×10^{11} V/m that are required to produce ultralow energy neutrons in LENR active sites
- For device working surfaces on which LENR active sites have already formed, there are a myriad of different, nanometer-to micron-scale electromagnetic (E-M), chemical, and nuclear processes that are operating simultaneously. Operation of LENR active sites involves extremely complex interplays between surface plasmon electrons, E-M fields, and many different types of nanostructures with various geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical and/or isotopic compositions
- Key take-away: electromagnetic, chemical, and nuclear processes can coexist and interact on small length-scales on many types of surfaces

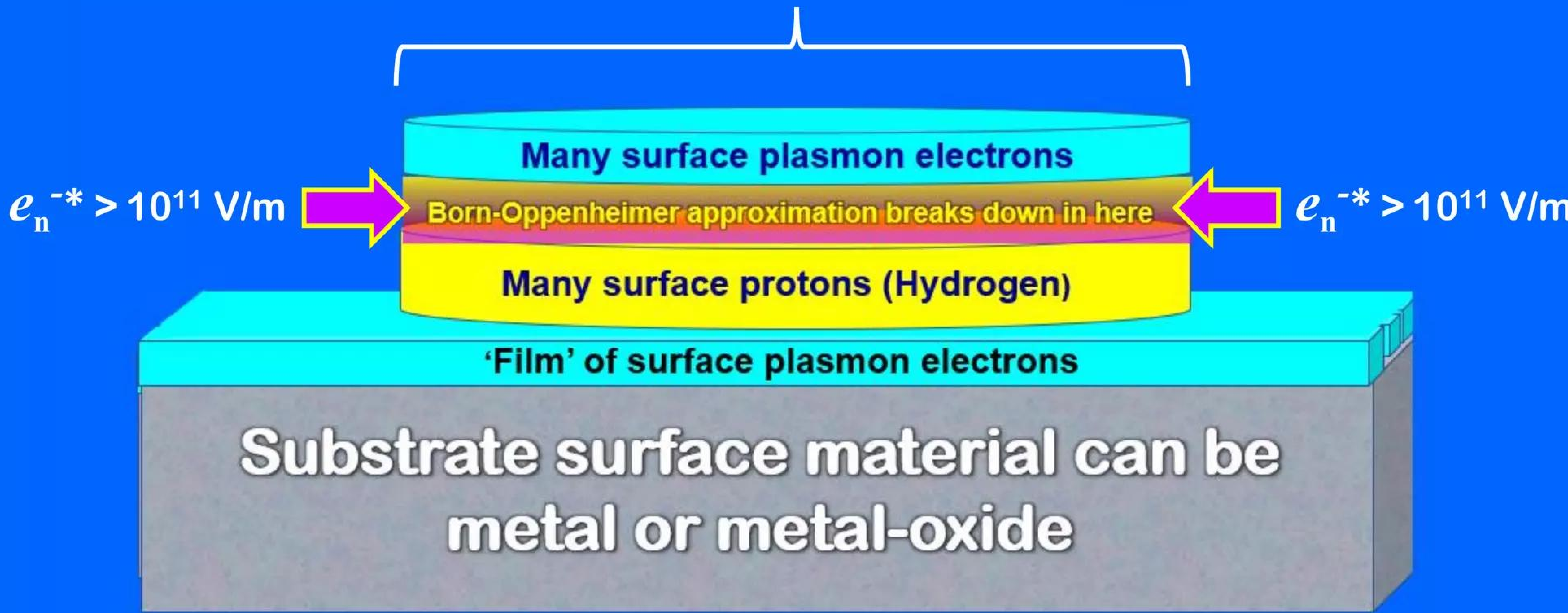
LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and SP electrons form spontaneously

High electric fields > 2.5 x 10^{11} V/m occur where Born-Oppenheimer breaks down

IDEALIZED AND NOT TO SCALE

Single nascent LENR active site; sizes range from ~ 2 nm up to 100 - 200 microns



Many-body SP electron + proton subsystems shown above form one Widom-Larsen active site on a planar surface; active sites can also form on surfaces of nanoparticles or at various types of interfaces

Summary of key steps in Widom-Larsen theory of LENRs

5-step process occurs in active sites over est. ~ 300 - 400 nanoseconds

W-L theory can explain why energetic neutron & gamma radiation are not emitted

1. Collectively oscillating, quantum mechanically entangled, many-body 'patches' of Hydrogen (+-charged protons or deuterons) will form spontaneously on fully loaded hydride surfaces & at certain interfaces: e.g. metal/oxide, gas/oxide, etc.

2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and protons within patches; application of input energy creates nuclear-strength local electric fields >2.5 x 10^{11} V/m - increases effective masses of surface plasmon electrons in patches

3. Heavy-mass surface plasmon electrons formed in many-body patches can then react directly with electromagnetically interacting protons; process creates neutrons and neutrinos via a many-body collective electroweak $e_n + p_n$ reaction

4. Neutrons collectively created in patches have ultralow kinetic energies and are all absorbed locally by nearby atoms – fluxes of energetic neutrons will not be emitted externally. Any locally produced or incident gammas will get converted directly into safe infrared photons (IR heat) by unreacted heavy electrons (Lattice patent US# 7,893,414 B2) - no deadly energetic gamma radiation will be emitted

5. Transmutation of elements and reworking of surfaces by active sites then begins

Protons form Q-M entangled patches on many types of surfaces

"Water-mediated proton hopping on an Iron oxide surface" Merte et al.

"Our use of both STM and DFT methods revealed that mobility of hydrogen on FeO(111) thin film grown on Pt(111) is completely dominated by water-mediated hopping mechanism. This mechanism, revealed for H atoms on fcc domains, consists of transfer of a surface proton to a water molecule, leading to short-lived hydronium ion species [H_3O^+] at the transition state. No bonding occurs between water molecule[s] and metal cations of FeO thin film."

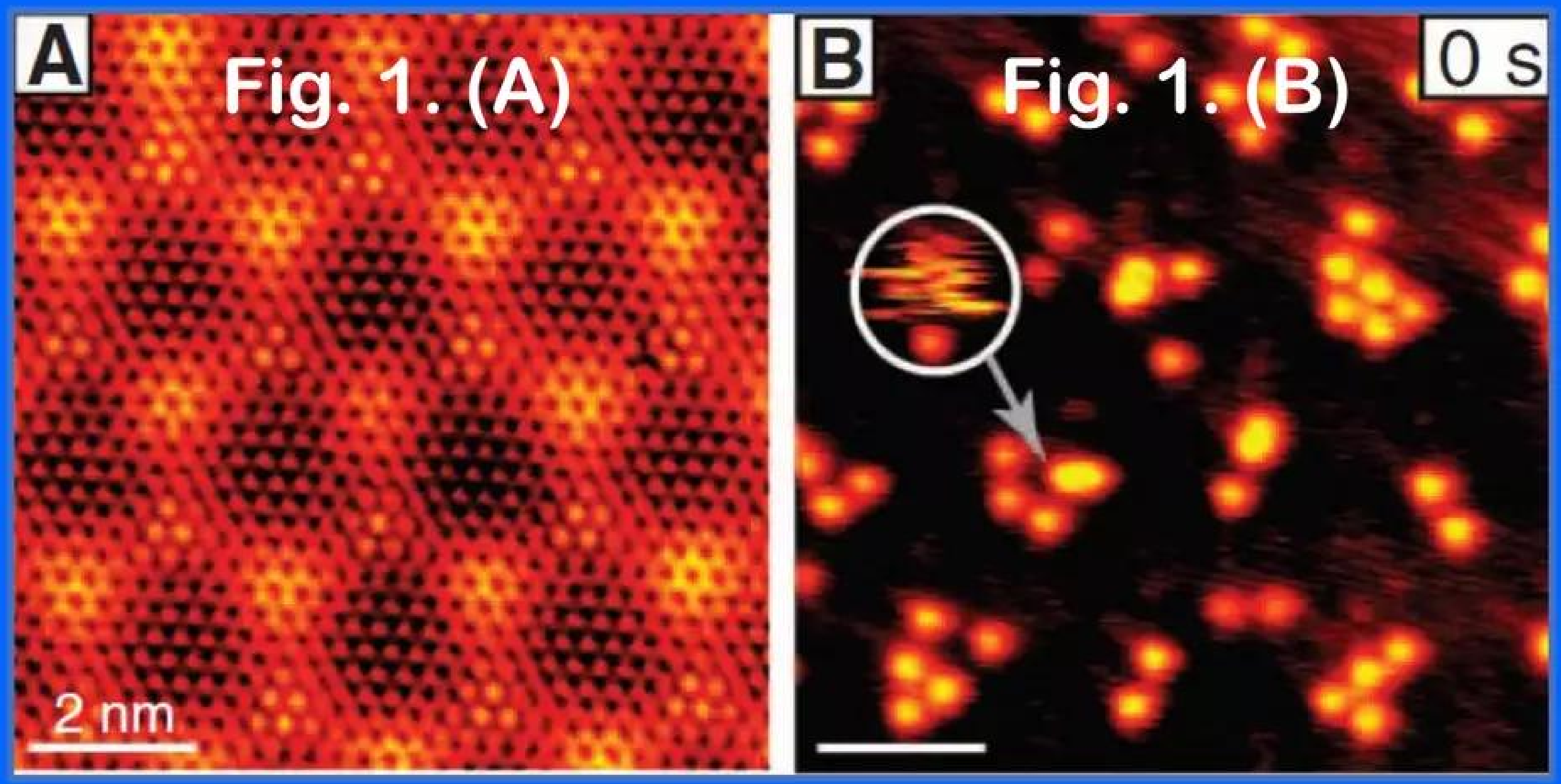


Fig. 1. (A) "Atomically resolved STM image of bare FeO film, showing moiré structure and protrusions due to individual Fe and O atoms."

Fig. 1. (B) "STM image of hydrogenated FeO film on Pt(111) at 105 K … hydrogen atoms (bright spots) diffuse rapidly [due to] water molecule."

"Water-mediated proton hopping on an Iron oxide surface"
L. Merte et al., *Science* 336 pp. 889 - 893 (2012)
http://science.sciencemag.org/content/336/6083/889.full

Protons form Q-M entangled patches on many types of surfaces

Merte et al: organized many-body clusters of protons on an FeO surface

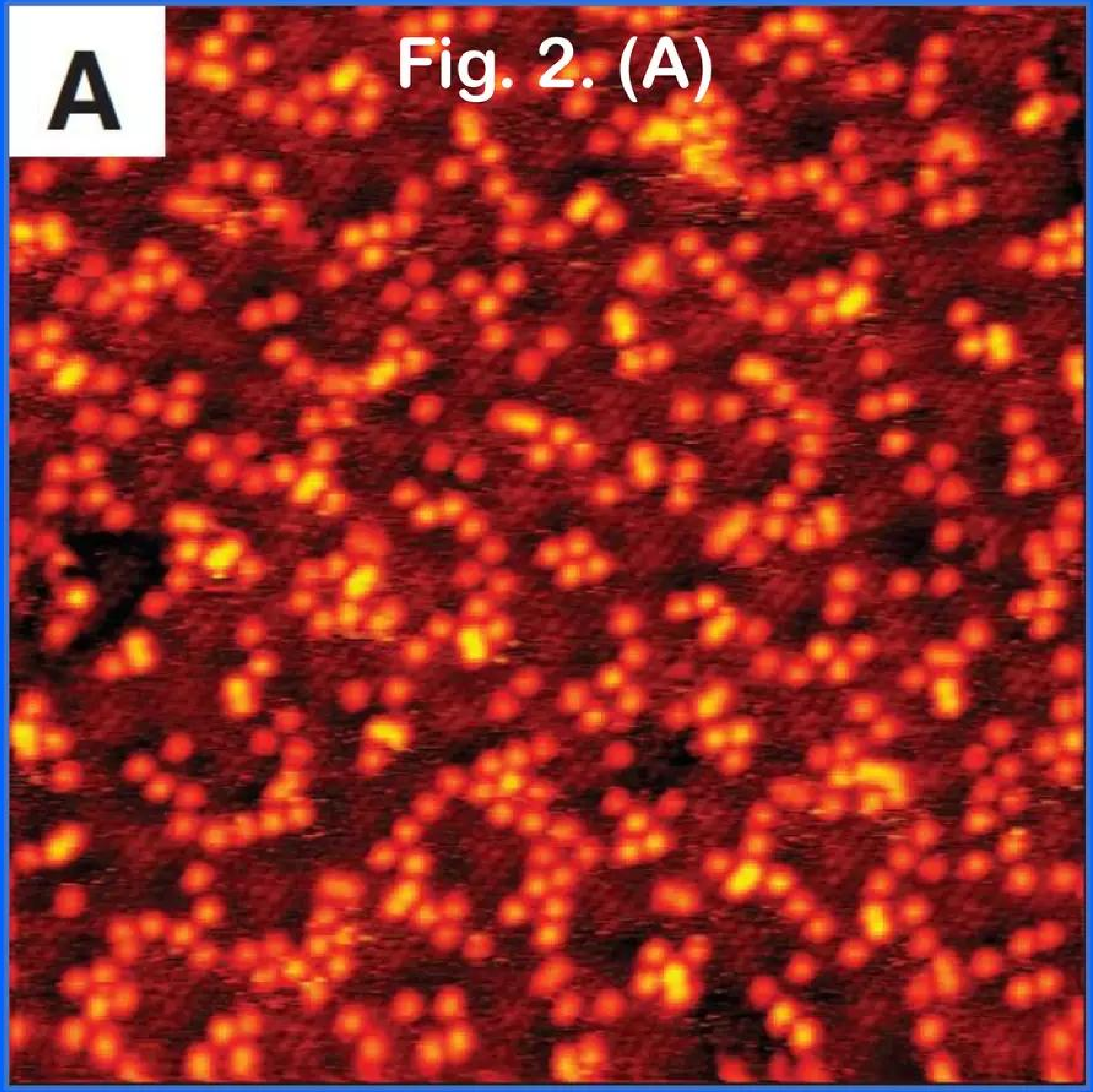


Fig. 2. (A) "Time-resolved STM measurements of hydrogen atoms on FeO(111)/Pt(111) at room temperature … frame [A - above] shows a single 180 Å × 180 Å STM image of FeO film; H atoms visible as bright protrusions."

Patches of p^+ protons form spontaneously on many surfaces

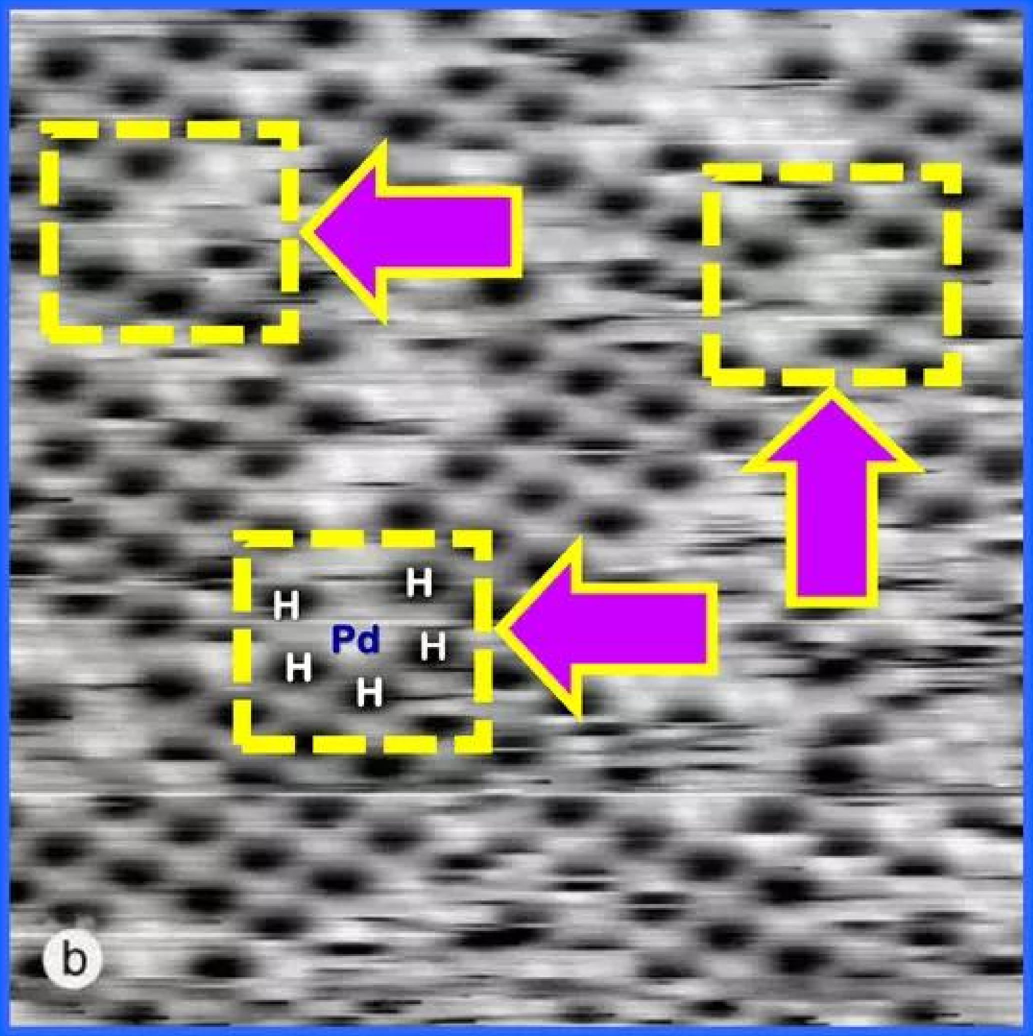
Physical sizes of LENR active sites ranges from 2 nm to 100+ microns

In metal hydrides bulk lattice loading H/metal must be > 0.80 for sites to form

Example shows formation of hydrogenous patches on loaded metallic hydride surface

- **Lattice comment:** image shows small many-body patches of protons on Pd surface. Visual inspection of STM image in adapted version of Fig. 1 reveals that under Mitsui *et al.'s* experimental conditions, PdHx ratios at many surface sites would appear to be comfortably above the minimal critical value of H/Pd > 0.80 known to be necessary for LENR triggering; PdHx H/Pd ratios seen at some surface sites can apparently range as high as x = 5.0 (see Figure 1)
- **Therefore:** similarly high PdHx 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. Consequently, high PdHx ratios could reasonably be expected to occur within nm to micron-sized, many-body, entangled hydrogenous active sites that are conjectured in the Widom-Larsen theory of LENRs

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



"Hydrogen absorption and diffusion on Pd (111)" T. Mitsui *et al.*
Surface Science 540 pp. 5 - 11 (2003)

http://www.researchgate.net/publication/229342506_Hydrogen_adsorption_and_diffusion_on_Pd(111)

Many-body collective quantum effects are crucial for LENRs

Enable LENR transmutation reactions at moderate temps & pressures

Many-body collective quantum $\boxed{e^{*}{}_{n}^{-} + p_{n}^{+} \rightarrow 1\ n_{ule} + \nu_{e}}$ effects

$$n_{ule} + (Z, A) \rightarrow (Z, A+1)$$

$$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \bar{\nu}_{e}$$

LENRs do not involve any 2-body fission or hot fusion reactions --- key step that produces ULE neutrons is many-body collective $e_n + p_n$ reaction between quantum mechanically entangled electrons and protons on solid-state surfaces or at interfaces

"Quantum entanglement in physics - What it means when two particles are entangled" Andrew Z. Jones for *ThoughtCo* July 10, 2017 https://www.thoughtco.com/what-is-quantum-entanglement-2699355

Credit: MARK GARLICK/SCIENCE PHOTO LIBRARY/Getty Images

Many-body collective quantum effects are crucial for LENRs

Surface plasmons in LENR active sites quantum mechanically entangled

SPs comprise up to ~10^{10} electrons and 'macroscopic' but are still Q-M entangled

"Plasmon-assisted transmission of entangled photons"
E. Altewischer *et al.*, *Nature* 418 pp. 304 - 306 (2002)

http://home.physics.leidenuniv.nl/~exter/articles/nature.pdf

- "Here we investigate the effects of nanostructured metal optical elements on the properties of entangled photons. To this end, we place optically thick metal films perforated with a periodic array of subwavelength holes in the paths of the two entangled photons. Such arrays convert photons into surface-plasmon waves --- optically excited compressive charge density waves --- which tunnel through the holes before reradiating as photons at the far side. We address the question of whether the entanglement survives such a conversion process. Our coincidence counting measurements show that it does, so demonstrating that the surface plasmons have a true quantum nature."
- "From a general perspective, the observed conservation of quantum entanglement for the conversion from photon → surface plasmon → photon is a demonstration of the true quantum nature of SPs."
- " … a simple estimate shows that SPs are very macroscopic, in the sense that they involve some 10^{10} electrons. Our experiment proves that this macroscopic nature does not impede the quantum behaviour of SPs …"

Many-body collective quantum effects are crucial for LENRs

Protons in LENR active sites are also quantum mechanically entangled

Quantum entanglement of protons is relatively widespread throughout Nature

- Protons found within a wide variety of many-body condensed matter molecular systems spontaneously oscillate coherently and collectively: their quantum mechanical (Q-M) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons. Amazingly, this behavior occurs even in comparatively smaller, much simpler molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexaclorometallate; see Krzystyniak *et al*. (2007) and Abdul-Redah & Dreismann (2006)
- Quoting from Krzystyniak et al.(2007): "… 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."
- Quoting 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."

Many-body collective quantum effects are crucial for LENRs

Protons go in-and-out of entanglement in 100 - 500 x 10^{-18} s time-frames

LENRs can take advantage of this because they work on even faster time-scales

"Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" C.A. Chatzidimitriou-Dreismann
Physica B: Condensed Matter 385 - 386 pp. 1 - 6 (2006)
https://arxiv.org/abs/cond-mat/0702180

- Quoting: "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 (2009) where they state "… mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."

Many-body collective quantum effects are crucial for LENRs

Protons in LENR active sites are also quantum mechanically entangled

"No other nucleus can manifest such an increase of its coherent cross-section"

"Evidence of macroscopically entangled protons in a mixed isotope crystal of $KH_pD_{1-p}CO_3$" F. Fillaux, A. Cousson, and M. Gutmann *Journal of Physics: Condensed Matter* 22 pp. 045402 (2010)

http://iopscience.iop.org/0953-8984/22/4/045402/pdf/0953-8984_22_4_045402.pdf

- Quoting: "Proposed theory is based on fundamental laws of quantum mechanics applied to crystal in question … It leads to macroscopically entangled states … This theory is consistent with a large set of experimental data (neutron diffraction, QENS, INS, infrared and Raman) and, to the best of our knowledge, there is no conflict with any observation. There is … every reason to conclude that the crystal is a macroscopic quantum system for which only nonlocal observables are relevant."
- "Protons are unique to demonstrating quantum entanglement, because they are fermions and because the very large incoherent cross-section can merge into the total coherent cross-section. No other nucleus can manifest such an increase of its coherent cross-section … They are evidences of macroscopic quantum correlations which have no counterpart in classical physics … This work presents one … case of macroscopically entangled states on the scale of Avogadro's constant in a mixed isotope crystal at room temperature … quantum theory suggests that macroscopic quantum effects should be of significance for many hydrogen bonded crystals."

LENRs occur in tiny active sites on surfaces or at interfaces

Many-body collections of protons and electrons form spontaneously

Shows nascent LENR active sites on surface; one of them has gone nuclear

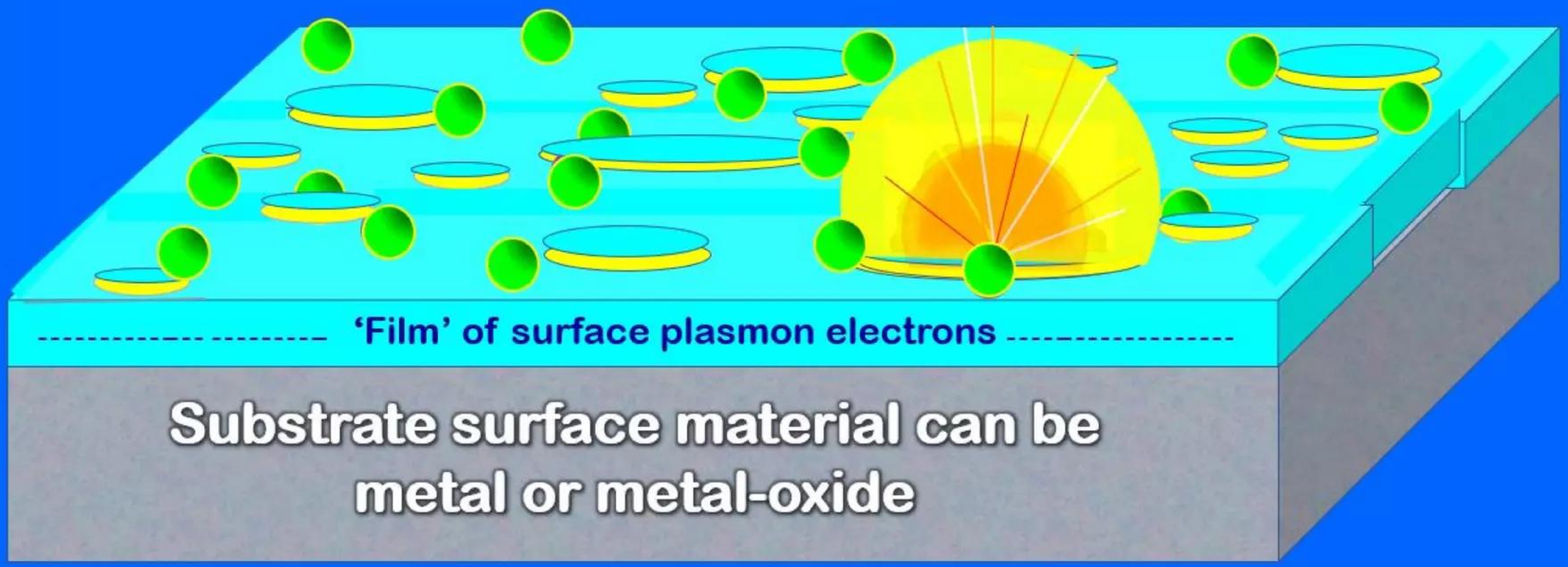
ULE neutrons are captured locally on atoms located very close to active sites

$n + (Z, A) \rightarrow (Z, A+1)$ [neutrons capture on nearby target NPs]

$(Z, A+1) \rightarrow (Z+1, A+1) + e_{\beta}^{-} + \overline{\nu}_e$ [beta$^-$ decay]

Often followed by β^- decays of neutron-rich intermediate isotopic products

= Metallic fuel nanoparticle (NP) 'targets'; e.g., bimetallic Ni_xPd_x NPs

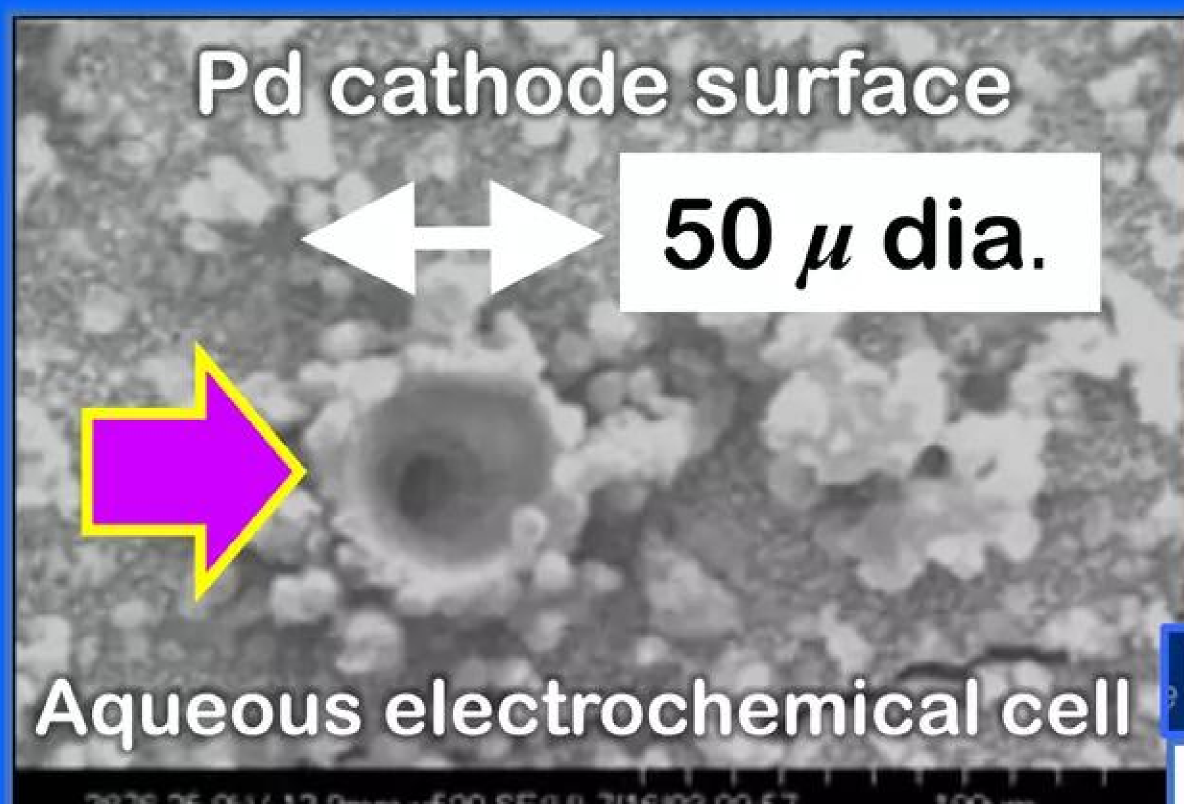


LENR active sites create distinctive surface nanostructures

Size of LENR active sites varies from 2 nanometers to 100 - 200 microns

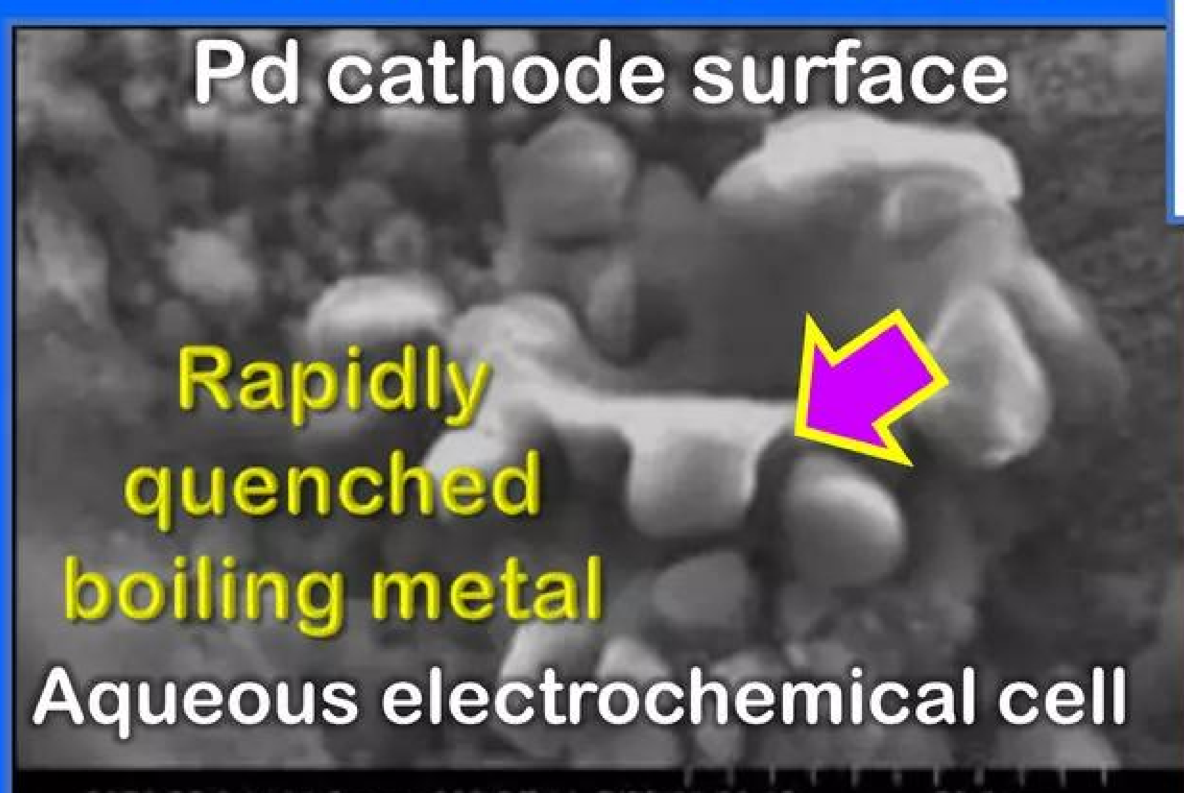
Post-experiment SEM images of Pd surface; infrared video of working Pd cathode

50 μ LENR active site crater on Pd cathode



Credit: P. Boss, U.S. Navy SPAWAR

LENR active site crater

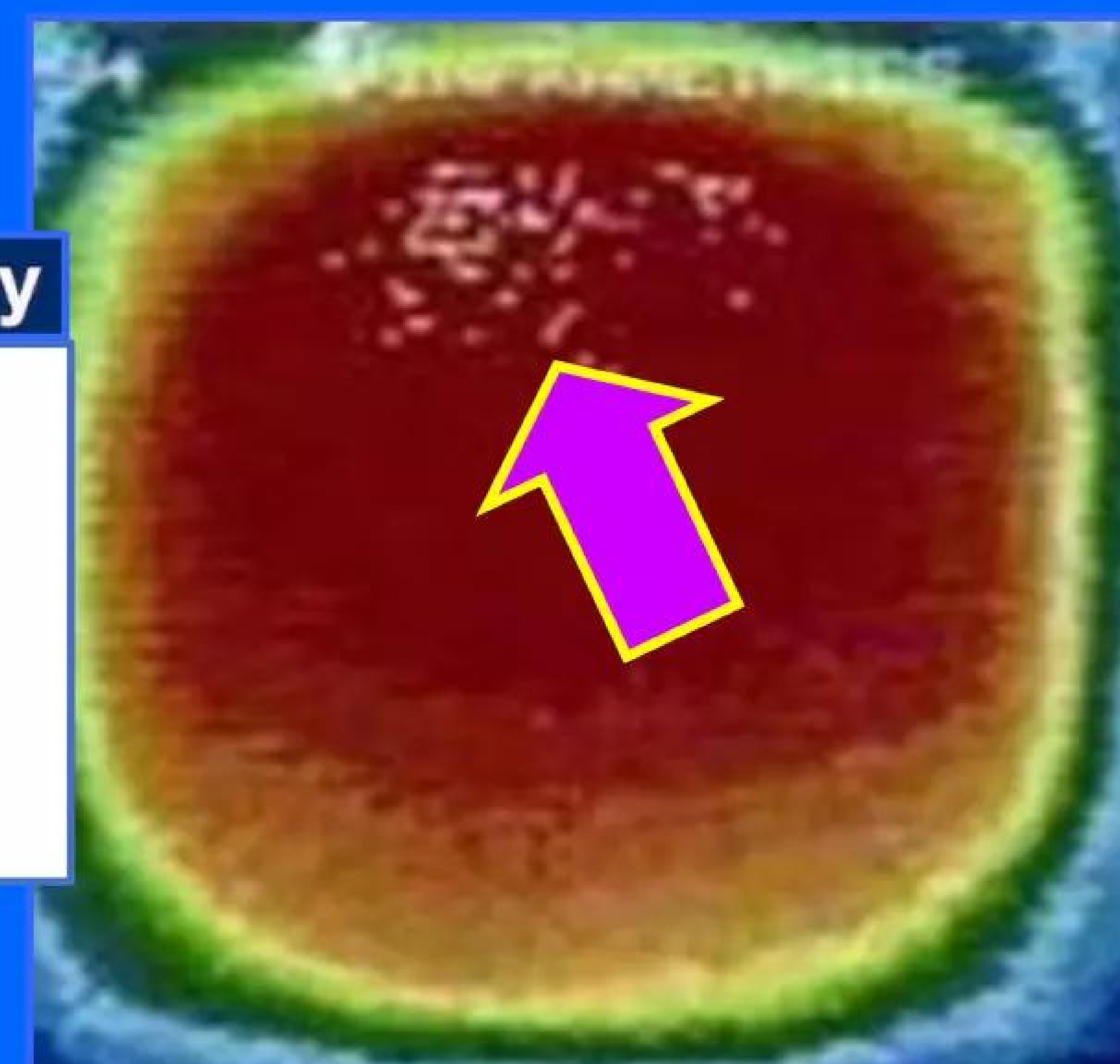


Credit: P. Boss, U.S. Navy SPAWAR

United States Navy
SPAWAR
Systems Center
PACIFIC

Navy video shows sites flickering rapidly

Infrared video: microscopic LENR hotspots are formed spontaneously then die-out on Pd cathode surface in electrochemical cell



http://www.youtube.com/watch?v=OUVmOQXBS68

Credit: P. Boss et al U.S. Navy SPAWAR (1994)

Boiling point of Palladium = 2,963°C

LENR active sites can create flash-melted craters on surfaces

SIMS and NanoSIMS detect isotopic shifts and transmutation products

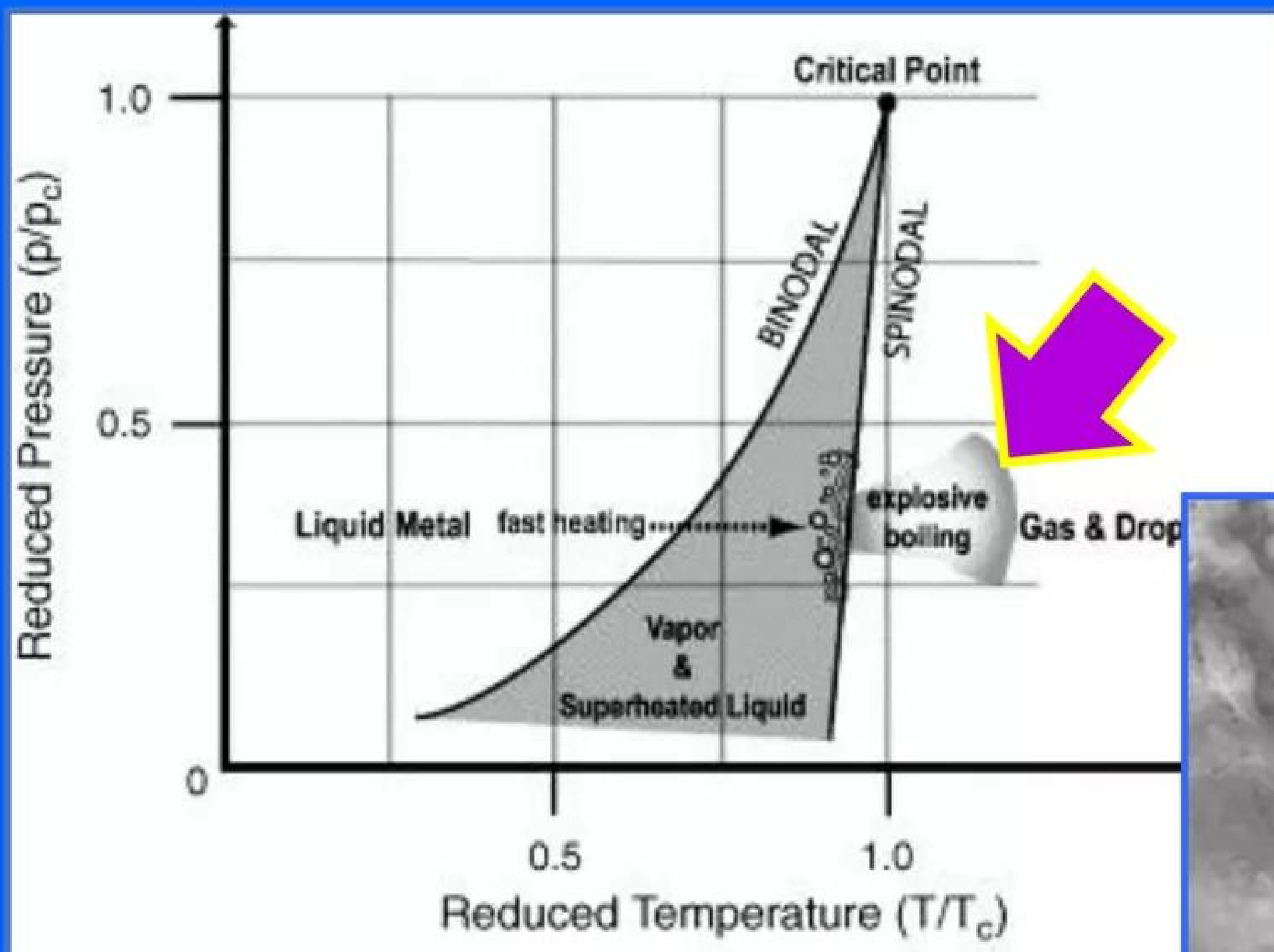
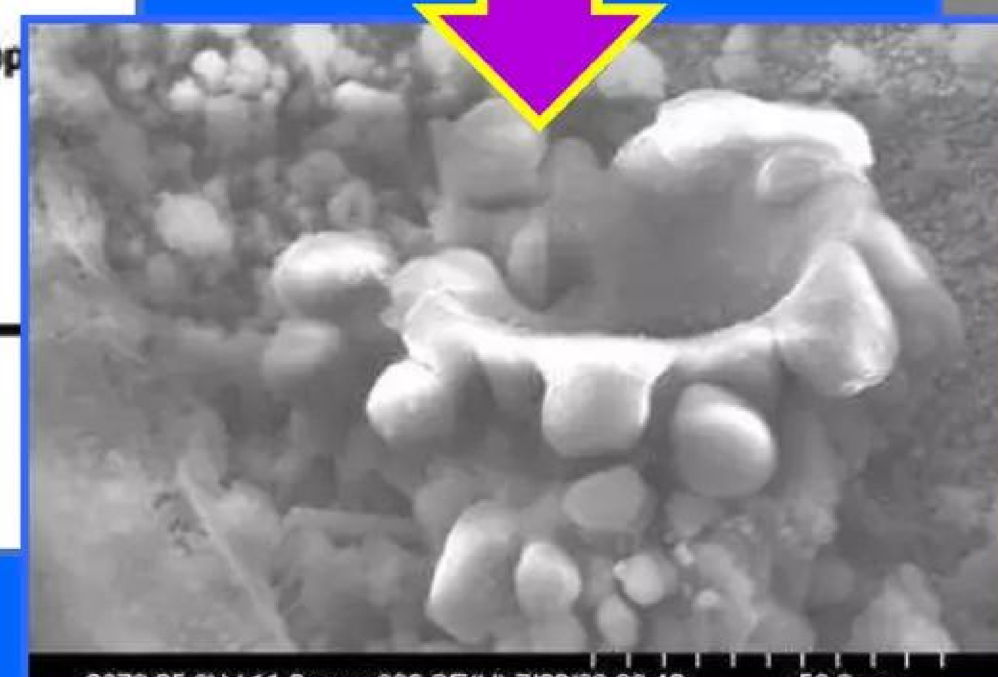


Fig. 1. Phase stability diagram of a liquid metal near the critical point. For fast heating, as obtained during *ns* laser ablation, the melt can be pushed close to critical conditions (superheating), which favors the realization of explosive boiling

LENR crater on Palladium cathode surface after electrolysis



Pd surface post-experiment SEM
P. Boss et al.
U.S. Navy - SPAWAR

Boiling point of Palladium = 2,963°C

Hydrodynamic analogue of boiling

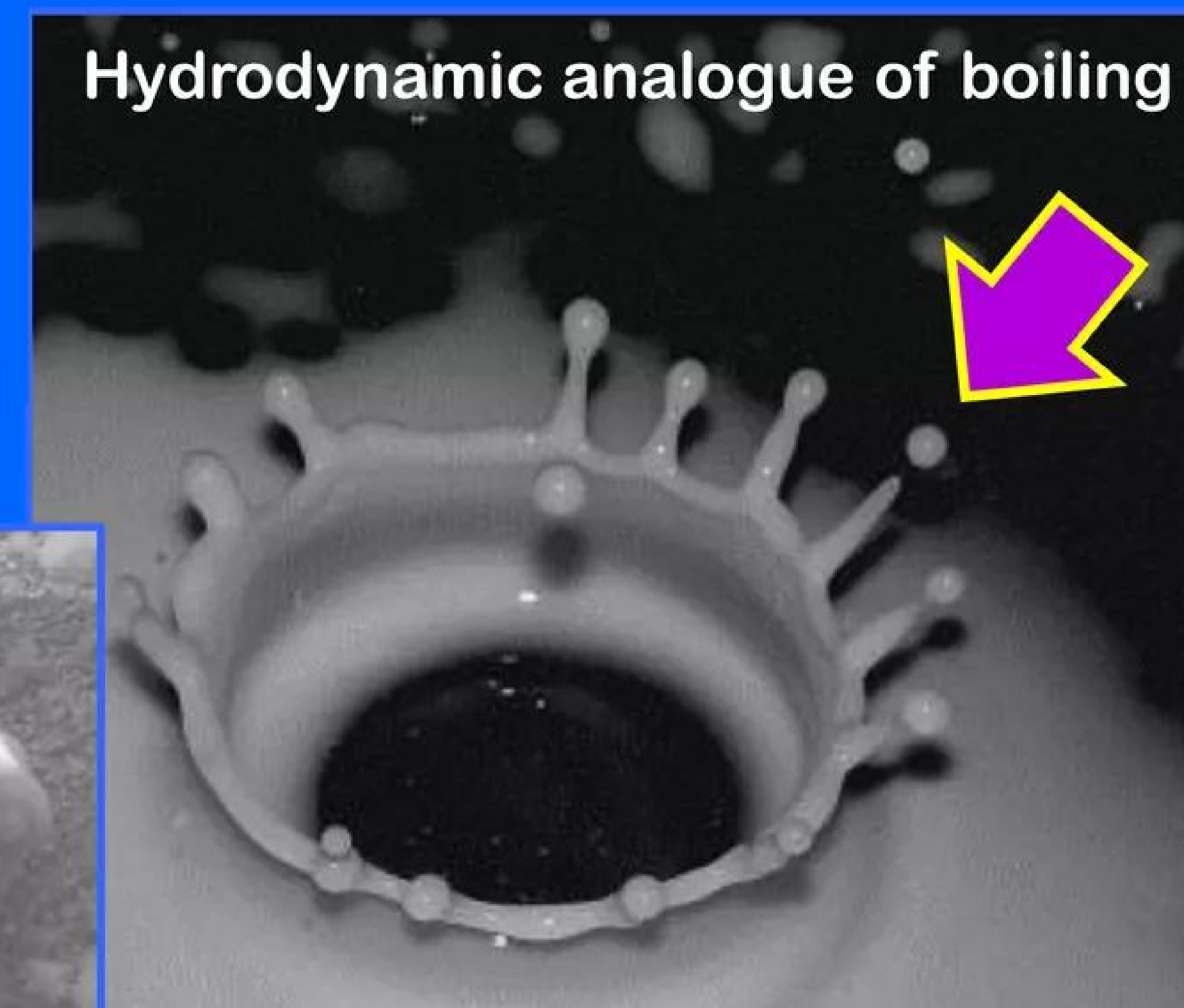


Fig. 2. Schematic visualization of the hydrodynamic evolution of a fluid system under and impulse stress (here milk). Note the non-deterministic formation of jets at the sides and their break-up into droplets. From Ref. [58].

Excerpted and quoted from: "Multiplicity and contiguity of ablation mechanisms in laser-assisted analytical micro-sampling" D. Bleiner and A. Bogaerts
Spectrochimica Acta Part B: Atomic Spectroscopy 61 pp. 421 - 432 (2006)
http://www.sciencedirect.com/science/article/pii/S0584854706000437

LENRs do not involve few-body fission or fusion processes

Safe ultralow energy neutrons created via many-body collective process

Neutrons are captured by target fuels which transmutes them and produces heat

Widom-Larsen theory explains hard radiation-free LENR transmutation of target fuels

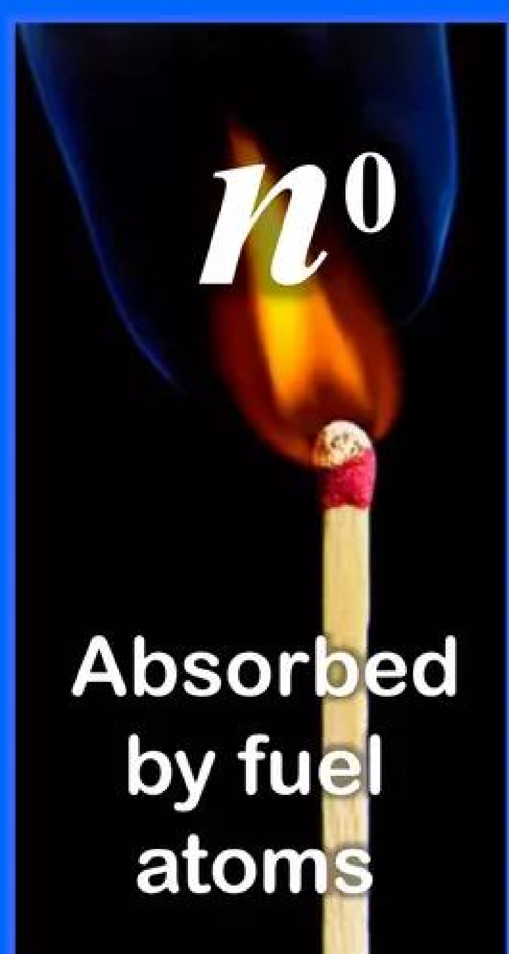
Transmutation

Neutrons + target fuel atoms → heavier elements + decay products + heat

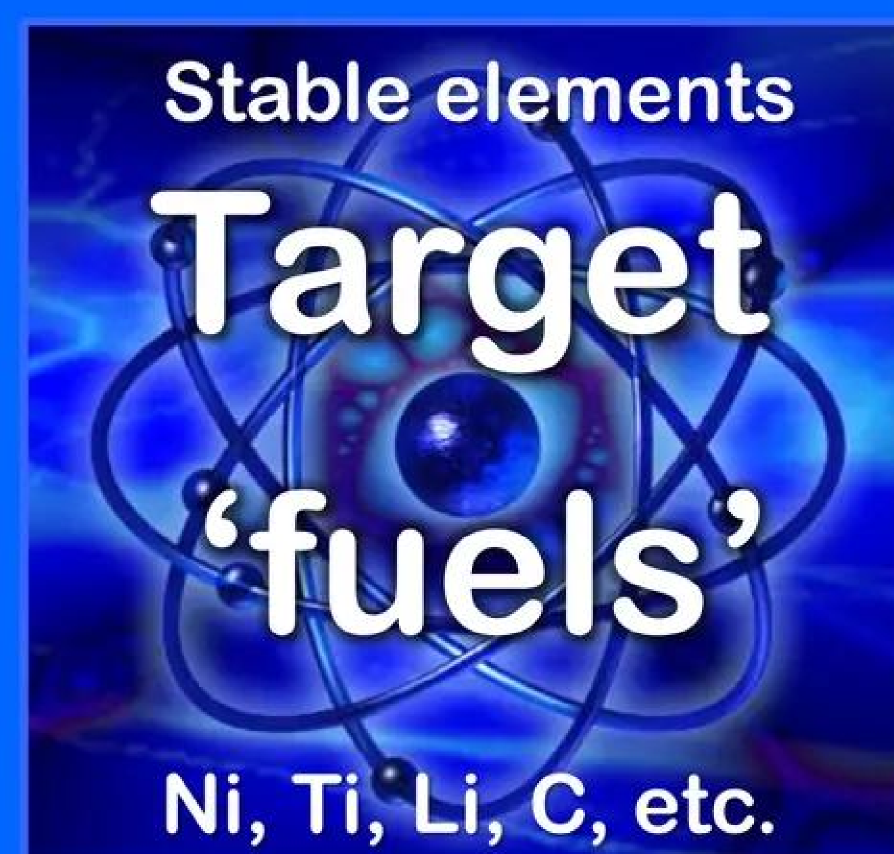
Catalytic neutron 'match'

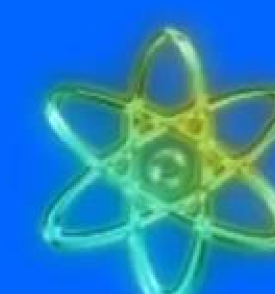
Neutrons are readily captured by LENR target fuels such as Nickel (Ni), Titanium (Ti), Lithium (Li), or aromatic Carbon (C) atoms

Direct conversion of neutron capture and decay-related gammas to IR plus local β or α particle scattering create heat

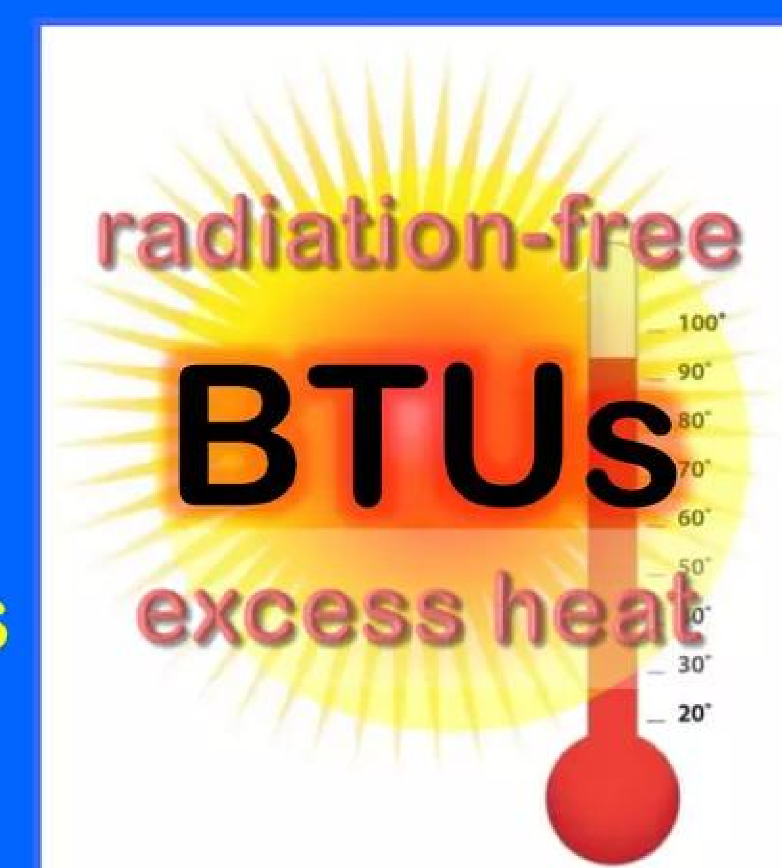


neutron + capture





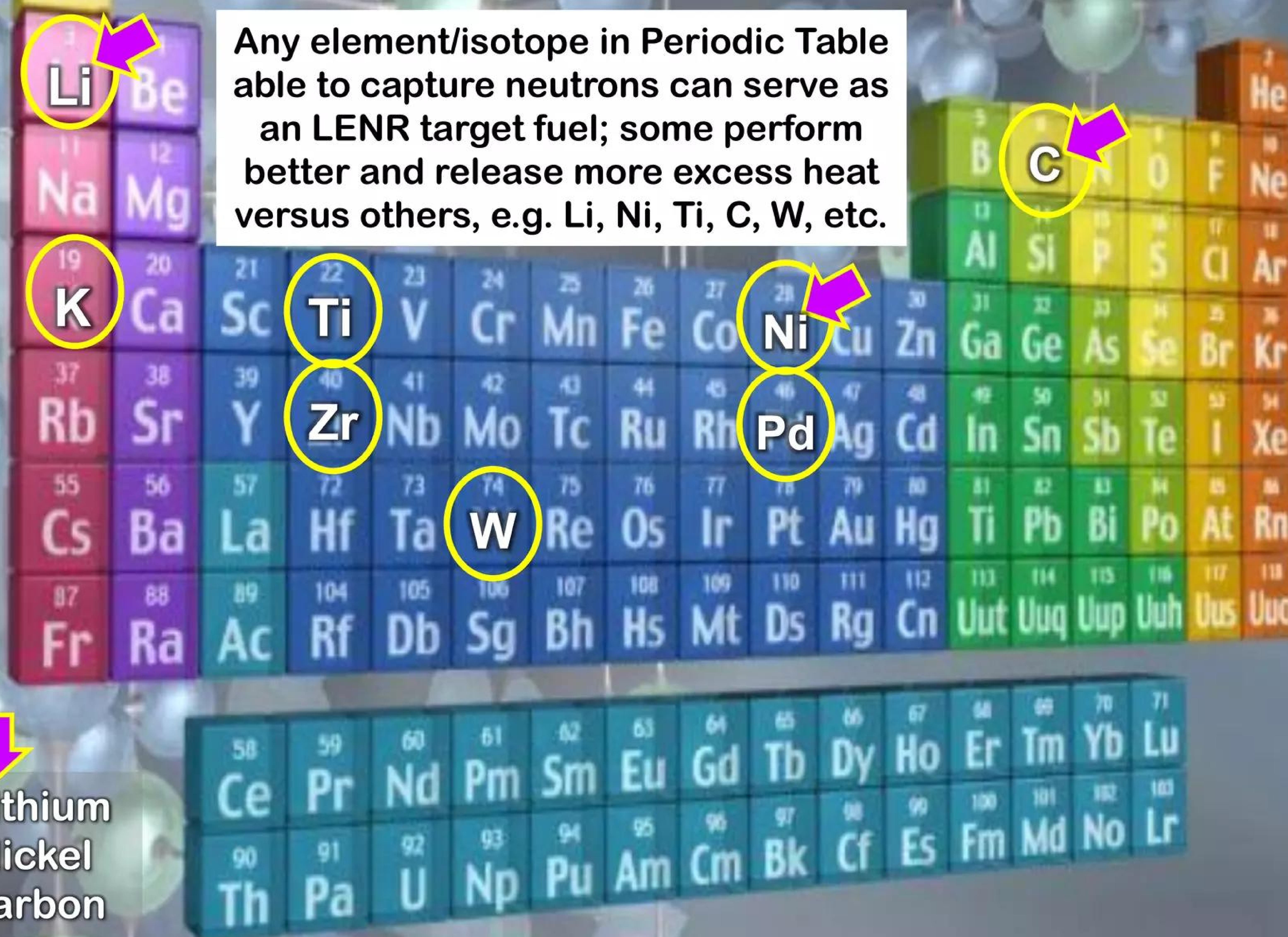
→ produces



LENR transmutation of fuel targets proceeds along rows of the Periodic Table

Neutron captures & β^- decays go from left-to-right along rows

Alpha decays triggered by neutron captures move in opposite direction

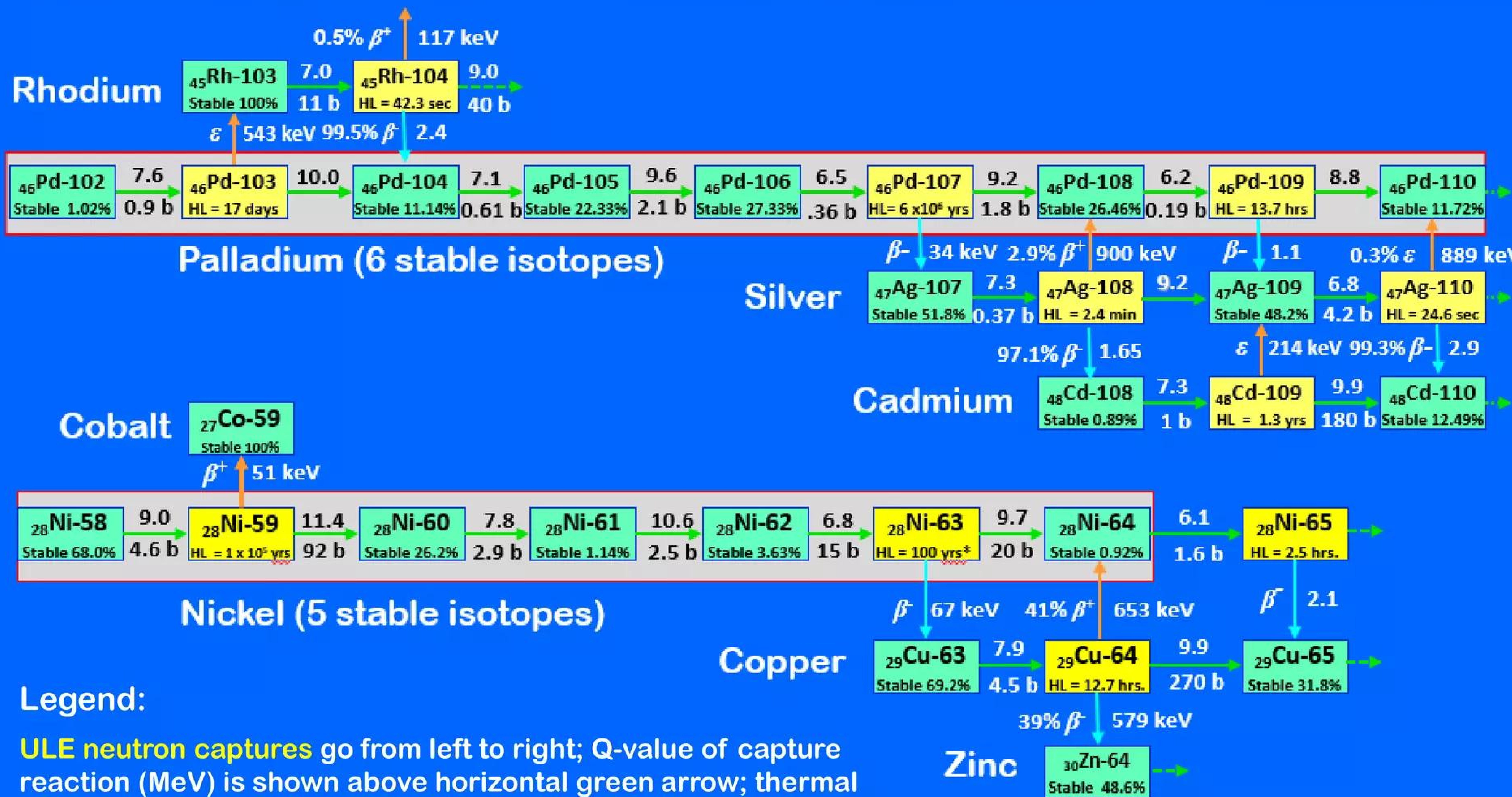


Any element/isotope in Periodic Table able to capture neutrons can serve as an LENR target fuel; some perform better and release more excess heat versus others, e.g. Li, Ni, Ti, C, W, etc.

Li = Lithium
Ni = Nickel
C = Carbon

Nickel (Ni) and Palladium (Pd) LENR transmutation networks

ULE neutron captures on Ni and Pd fuel produce substantial excess heat



Legend:

ULE neutron captures go from left to right; Q-value of capture reaction (MeV) is shown above horizontal green arrow; thermal neutron capture cross-section (barns, if known) shown below:

Beta-minus decays go from top to bottom; indicated with blue vertical arrow with Q-value (MeV) to right of arrow:

Electron capture (e.c.) and beta-plus decays go from bottom to top and indicated by orange vertical arrow; Q-value is to right:

Energetics for LENR transmutation of Nickel (Ni) target fuel

Estimated net gain ratio (total energy output/total energy input) = 12.14

Specific energy (MJ/kg) of Ni target fuel > 3 million x larger vs. H_2 combustion

Isotope Capturing ULM Neutron or Beta decaying	Natural abundance of stable isotope	Neutron capture Q-value in ~MeV (all are + values)	Contribution to weighted average based on natural abundance	**Comments and calculations** Assume Hydrogen (H_2) used for proton (p^+) source
Ni-58	68.0%	9.0	6.94	Assume ULE neutron captures on Ni-58 and Ni-59 are equally weighted average because N-59 has highest neutron capture cross-section of all Ni isotopes 9.0 + 11.4 = 20.4 / 2 = 10.2 MeV 10.2 x 0.68 = 6.94
Ni-59	Nil	11.4		
Ni-60	26.2%	7.8	2.04	7.8 x .262 = 2.04
Ni-61	1.14%	10.6	0.12	10.6 x .0114 = 0.12
Ni-62	3.63%	6.8	0.30	Similar assumptions to calculation for Ni-58 and Ni-59 6.8 + 9.7 = 16.5 / 2 = 8.25 8.25 x 0.0363 = 0.30
Ni-63	Nil	9.7		
Ni-64	0.92%	6.1	0.07	Similar assumptions to calculation for Ni-58 and Ni-59 6.1 + 9.0 = 15.1 / 2 = 7.55 7.55 x 0.0092 = 0.07
Ni-65 (decay)	Nil	2.1		
Weighted average energy release (MeV) per neutron capture on Nickel fuel target			9.47 MeV	9.47 / 0.78 (cost ULEN in MeV) = 12.14 Energy gain ratio

Gain

Widom-Larsen theory enables commercialization of LENRs

Microscopic reproducibility of active sites is the key to commercialization

Stage of LENR technology is presently TRL-4; existing nanotech can be leveraged

Lattice's LENR thermal device engineering program has three key stages:

(1) Reproducible fabrication of nanostructures for well-performing LENR active sites

(2) Scale-up the device heat output by increasing # of active sites per unit area/volume

(3) Select and integrate energy conversion subsystems suitable for specific applications

- Main goal should be to first get key LENR effects --- especially excess heat and transmutations --- working reliably on nanoscopic length scales. One must be able to reproducibly create rationally designed nanoparticulate structures with dimensions ranging from nm to microns that are fabricated using selected, off-the-shelf nanotechnology techniques and methods. Such nanostructures are then emplaced, along with chosen fuel atoms (e.g., Lithium, Carbon, Nickel, etc.) very close to what will become LENR active sites on device working surfaces
- Once microscopic reproducibility of active sites is achieved, output of LENR heat sources could be readily scaled-up, either by (1 – higher area-density) fabricating larger area-densities of affixed nanostructures that facilitate formation of LENR active 'hot spot' sites on device surfaces; or by (2 – higher volumetric density) injecting larger quantities of specially designed target fuel nanoparticles into volumetrically larger reaction chambers containing dusty Hydrogen plasmas that may have spatially organized magnetic fields present inside reaction chambers

Widom-Larsen theory enables commercialization of LENRs

Applied nanotechnology and LENRs are mutually joined at the hip

Development risks can be reasonable thanks to Widom-Larsen and nanotech

Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green CO_2-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations in nanoparticle fabrication techniques, as well as an array of new discoveries in advanced materials science.

Visualization of surface plasmon electric field strength gradients on substrate surface

NEDO project advanced stage of LENR technology to TRL-4

Mainly engineering is required to go from "ugly" TRL-4 devices to TRL-9

European
Commission

Technology Readiness Levels

TRL 0: **Idea**. Unproven concept, no testing has been performed.

TRL 1: **Basic research.** Principles postulated and observed but no experimental proof available.

TRL 2: **Technology formulation**. Concept and application have been formulated.

TRL 3: **Applied research**. First laboratory tests completed; proof of concept.

TRL 4: **Small scale prototype** built in a laboratory environment ("ugly" prototype).

TRL 5: **Large scale prototype** tested in intended environment.

TRL 6: **Prototype system** tested in intended environment close to expected performance.

TRL 7: **Demonstration system** operating in operational environment at pre-commercial scale.

TRL 8: **First of a kind commercial system**. Manufacturing issues solved.

TRL 9: **Full commercial application**, technology available for consumers.

LENR technology had stagnated at TRL-3 for at least 15 years

NEDO project utilized Widom-Larsen theory & nanotech to achieve TRL-4

- For over 15 years prior to NEDO project, LENR technology stagnated at ~ TRL-3. During that time, vast majority of best-practices LENR experimental systems were DC current-driven aqueous H_2O or D_2O electrochemical cells with bulk metal ~ cm^2 99% pure Pd metal cathodes, 99% pure Pt anodes, and various salts dissolved in electrolytes. Calorimetrically measured excess heat production in such systems typically ranged from several milliwatts up to 0.5 Watts (average was only tens of milliwatts; values > 1 Watt were quite rare). Repeatability and duration of significant excess heat production varied widely. During successful experiments, heat was sporadic at milliwatt levels and typically only lasted for several days. In labs with best experimental results, excess heat production of 100s of milliwatts for several days and 10 - 20% repeatability for certain batches of electrodes were heretofore considered best practices, state-of-the-art results
- 2015 - 2018: Japanese government-funded NEDO group-project advanced LENR thermal device technology from TRL-3 to solid TRL-4. By wittingly or unwittingly utilizing device engineering precepts of Widom-Larsen theory and application of nanotech, project scientists successfully increased average LENR device excess heat production by ~ 1,000x (typical device excess heat output increased from milliwatts up to 5 Watts) relative to prior best-practices experimental results; this advanced LENR technology from TRL-3 to TRL-4. This major gain in LENR device performance was achieved in 2.5 years with expenditures under US$54 million

NEDO project achieved reproducible Watt-level excess heat

Watt-level heating produced without emitting any deadly hard radiation

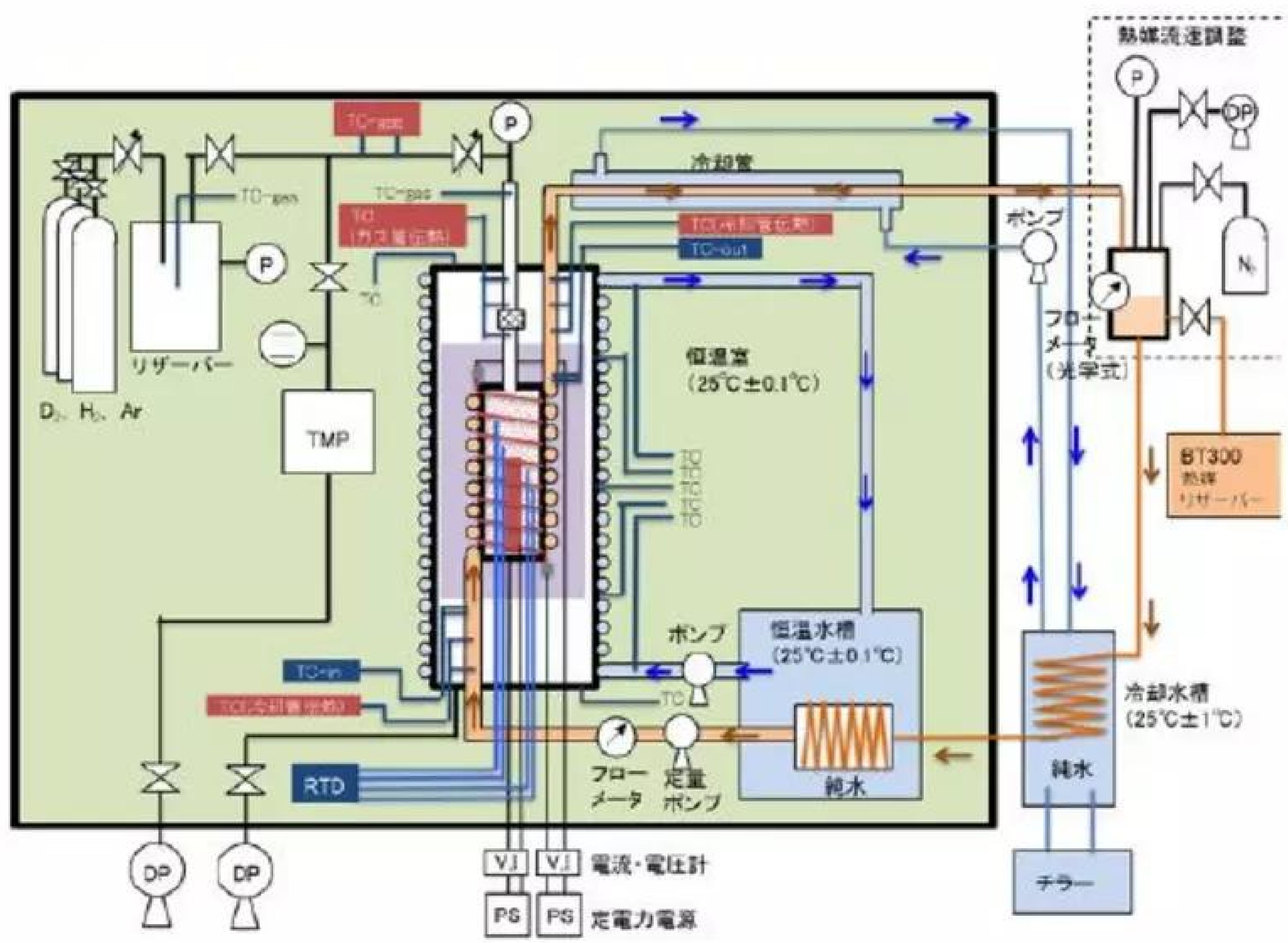
- Excess heat was produced in ~ 80% of experiments; whenever excess heat is created, it is most often at Watt-levels or better at operating temperatures of 200 - 400º C. Duration of excess heat production ranged up to weeks, which is non-trivial. Such LENR device behavior represents excellent reproducibility for complex early-stage technology; are best-ever results reported to date in field
- Watt-level excess heat is produced in Hydrogen (H)- and Deuterium (D)-loaded systems. This is consistent with & predicted by Widom-Larsen theory of LENRs
- No deadly energetic (MeV-energy) gamma or neutron radiation was detected during Watt-level excess heat production during any project experimental runs. Observations are consistent with & predicted by Widom-Larsen LENR theory
- Substantial variation in heat production between duplicate samples under otherwise similar conditions is likely due to subtle nanoscale heterogeneities
- In Lattice's opinion, NEDO project's outstanding experimental results changed LENRs' Technology Readiness Level (TRL) from TRL-3 to TRL-4 (European Commission definitions). This is important step for commercialization efforts
- Lattice recently discovered surprisingly deep causal similarities between condensed matter electroweak nuclear catalysis ($e + p$ reaction), enzymatic catalysis, and chemical catalysis --- LENRs are not as exotic as some may think

NEDO LENR device experiments use unshielded apparatus

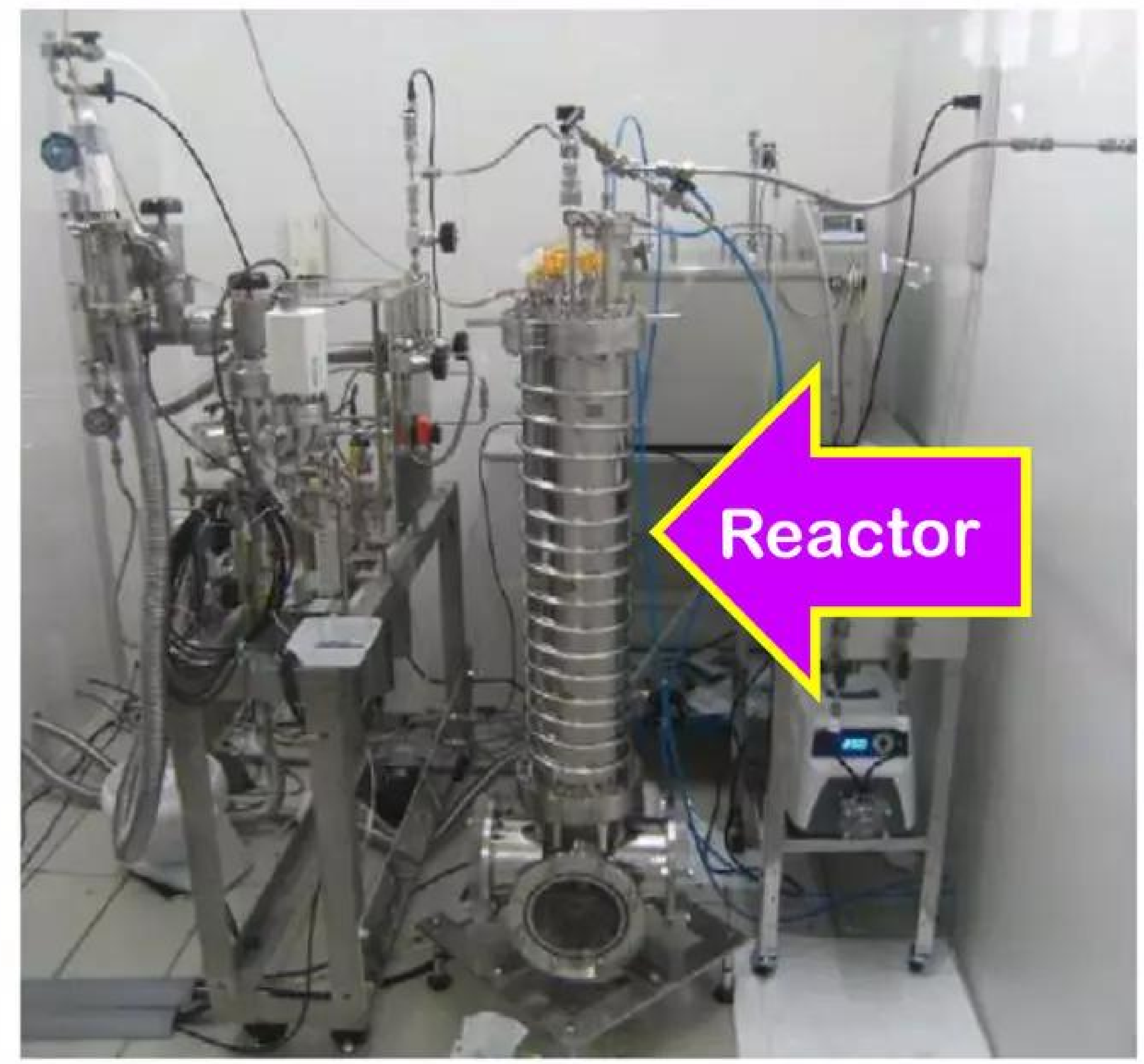
Schematic diagram at left describes details of the experimental apparatus

Technova Seminar 2018/3/2

新規高精度熱評価装置（東北大学ELPH）を設計・製造・組み立てし、発熱試験に成功：共同実験



装置構成
Schematics of facility



東北大MHE装置外観
Main part of Tohoku MHE facility

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NEDO LENR device nanofabrication and testing project

~ 100 grams 'fuel' NPs produced avg. 5 Watts excess heat for 2 - 45 days

H_2 (D_2) provide protons (deuterons); surface plasmons provide electrons for $e + p$

$$e_{n}^{-*}{}_{sp} + p_{n}^{+} \rightarrow n^{0} + \nu_{e}$$

- **NEDO project designed and fabricated nanoparticulate LENR devices that produced 3 to 24 Watts (average ~ 5 Watts) of excess heat for periods ranging from several days up to 45 days with excellent overall experimental repeatability of > 70 - 80% on standardized apparatus**
- **LENR devices consisted of ~ 90 - 120 grams of specially fabricated, purpose-engineered ~ 2 nm metallic LENR 'fuel' nanoparticles hosting nascent LENR active sites that were mixed with ~ 1 kilogram of much larger 1 mm ZrO_2 (most experiments) or SiO_2 metal-oxide "filler beads"**
- **Mixtures of metallic nanoparticles and filler beads were poured into cylindrical stainless-steel 500 cc reaction chambers that were then sealed and filled with 99% pure Hydrogen (H_2) or Deuterium (D_2) gas**
- **After being filled with H_2 or D_2 + 'fuel' NPs + fillers and sealed, reactors heated to device working temperatures of 200 - 400° C, after which excess heat production above total input power was measured over duration of experiments with a sensitive integrated calorimetry system**

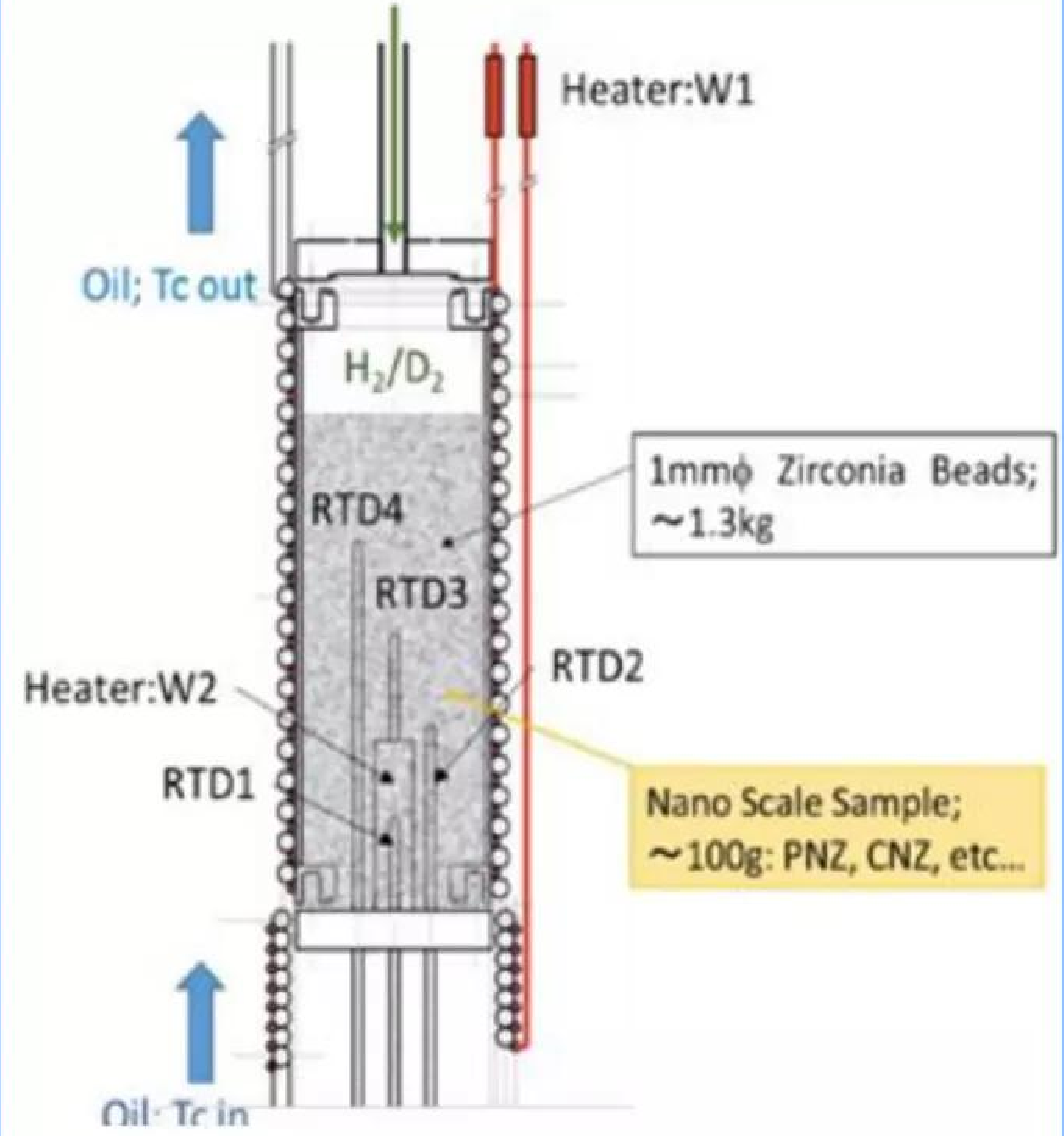
NEDO project: rigorous standardized experimental methods

LENR test devices: engineered nanoparticles with varied compositions

Overview of NEDO project LENR device materials composition and fabrication

- Designed 2 nm mono- and bi-metallic nanoparticle LENR test devices comprised of metallic Ni, Pd, and Cu along and 1 mm ZrO_2 or SiO_2 oxide filler beads; fabricated via standard nanotech methods
- Solid-state LENR devices were amorphous. Had nanometer-scale domains consisting of alloyed metals with various molar ratios; Ni, Pd, Zr will form good hydrides when exposed to Hydrogen
- LENR device types tested [metal nanoparticles; oxide filler beads]: PS (Pd; SiO_2), CNS (Cu_x/Ni_x; SiO_2), PNZ (Pd_xNi_x; ZrO_2), or CNZ (Cu_x/Ni_x; ZrO_2)
- LENR test devices analyzed and characterized before-and-after experimental runs with some or all of following techniques: XRD, SOR-XRD, SOR-XAFS, TEM, STEM/EDS, ERDA, and ICP-MS, and others – are not publicly reporting ANY pre/post-experiment mass spectroscopy data on devices

NEDO project reactor



NEDO PNZ7k Ni_7 / Pd_1 'fuel' nanoparticle loaded with D(d^+)

D(H)/metal-atom ratio > 0.80 for many-body d^+ patches to form on surfaces

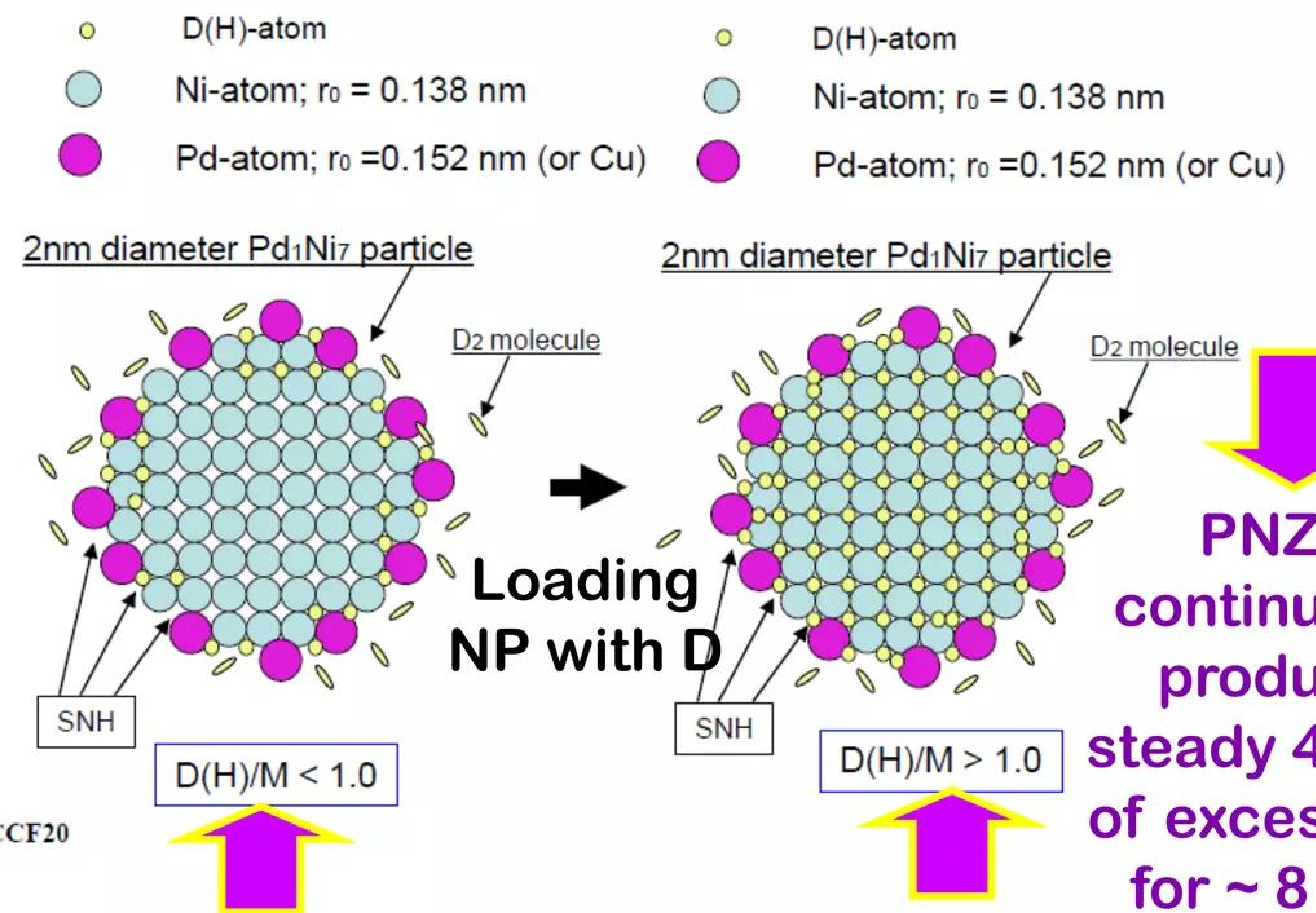
Widom-Larsen: LENR active sites form spontaneously on nanoparticle surfaces near regions of direct contact between Ni_7 / Pd_1 nanoparticles & ZrO_2 filler beads

4 Watts

Sample	Mass (g)	Molar ratio				ZrO_2 filler mass (g)
		Ni	Pd	Zr	O	
PNZ7k	99.8	**0.306**	**0.044**	**0.650**	0.274	1531
calcined at 450°C·60h		7 : 1				

4 Watts

SNHs are prepared by O-reduction to start D(H) absorption (left)
And D(H)/M loading ratio exceeds 1.0 level (right)



ICCF20

PNZ7k continuously produced steady 4 Watts of excess heat for ~ 8 days

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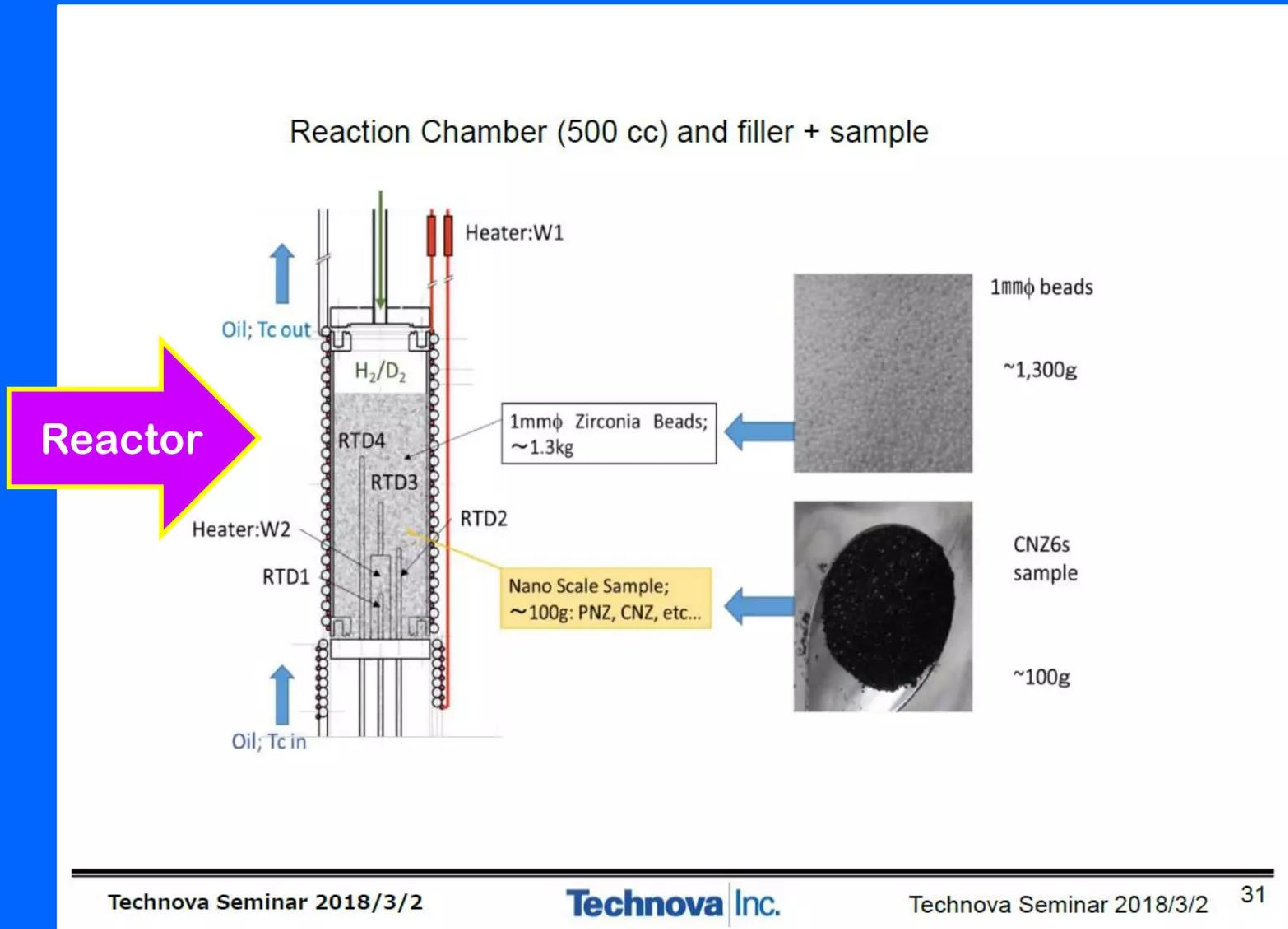
Example of LENR reactor used in NEDO project experiments

Metallic LENR ‘fuel’ NPs and metal-oxide filler beads loaded into reactor

~100$^+$ grams of Ni_x/Pd_x fuel NPs + 1,300 grams of 1 mm Zirconia (ZrO_2) filler beads

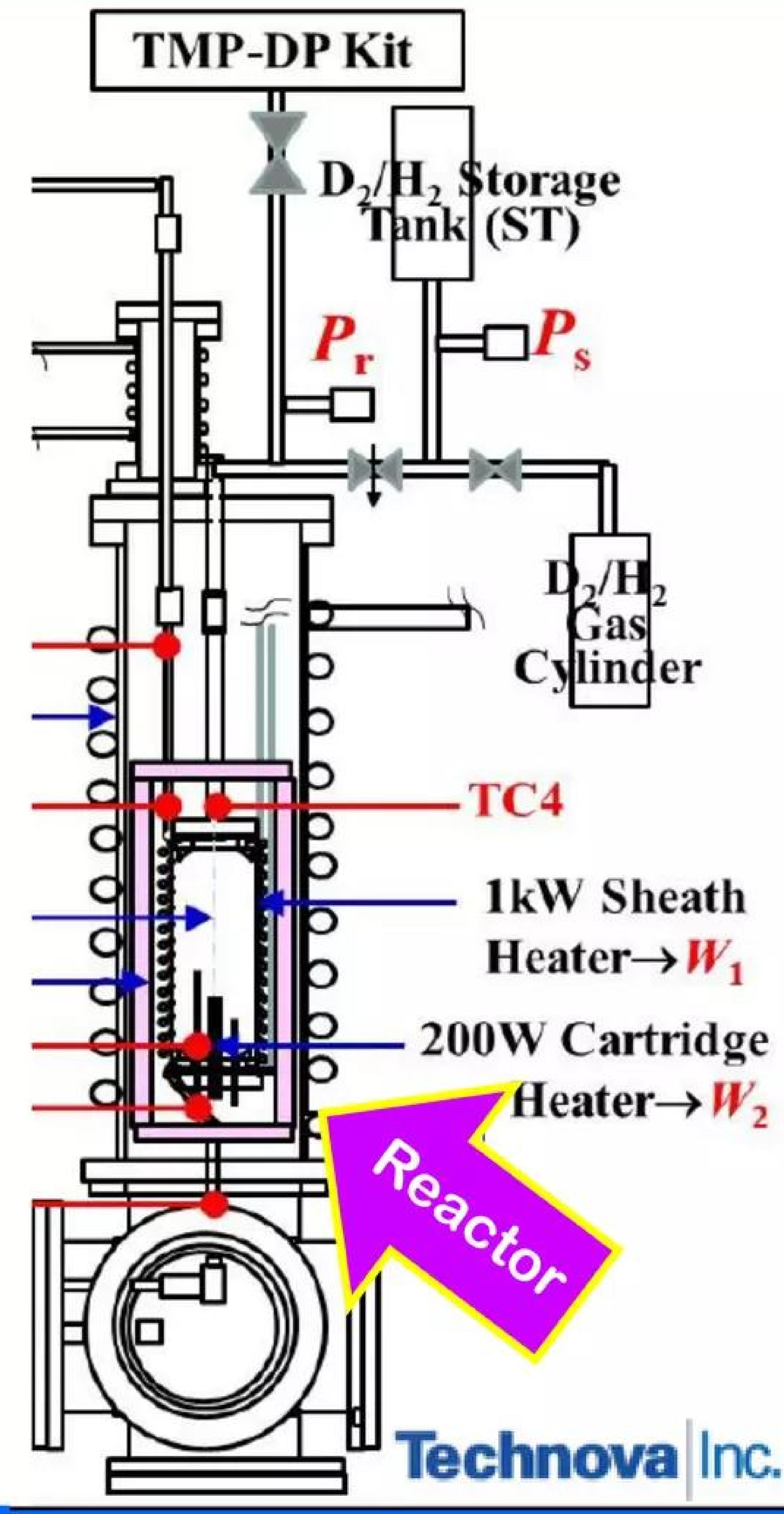


NEDO project utilizes standardized apparatus and methods

Integrated calorimetry accurately measures excess heat production in RC

Generic overview of experimental run after LENR device nanomaterials fabrication

1. Non-destructively characterize nanoparticulate materials
2. Pour 'fuel' NPs + filler beads into reaction chamber (RC)
3. Close RC and open valve: admit either 99+%-pure D_2 or H_2 gas into reaction chamber at ~1 atm pressure and room temp; then close valve (RC sealed); measure excess heat production via calorimetry (should be negligible at STP)
4. Use external source of power to heat reaction chamber to working temperatures of 150 - 450º C (avg. 200 - 300º C)
5. Conduct experimental run for planned period of time: continuously measure excess heat production inside RC via calorimetry (excess heat ≈ measured total thermal output from RC minus total thermal input into RC) for remaining duration of given experimental runs
6. Stop experiment; remove all sample materials from RC
7. Post-experiment: analyze LENR device nanomaterials



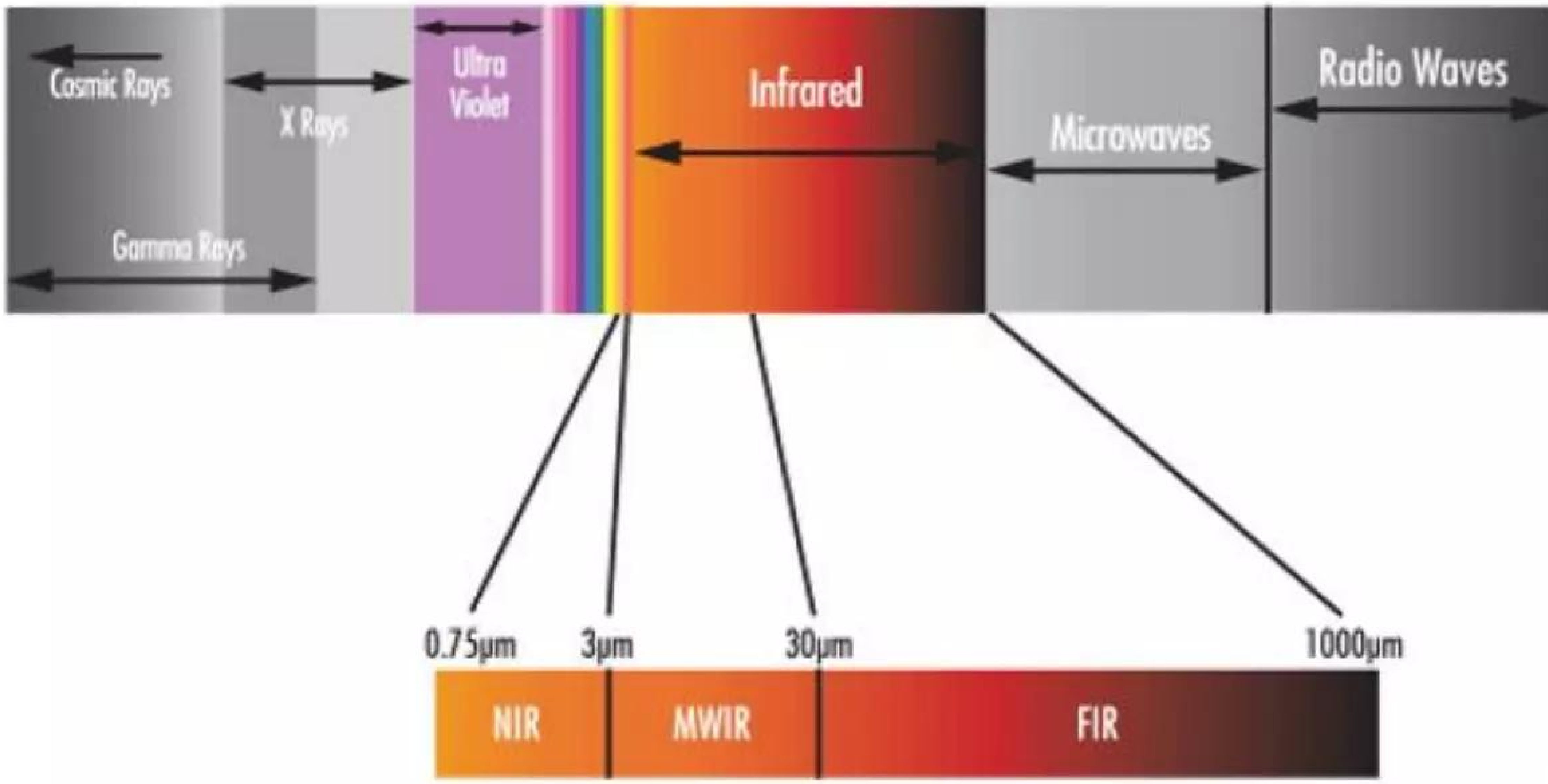
Widom-Larsen: input energy is required to produce neutrons

NEDO experiments: input energy mainly in form of blackbody IR photons

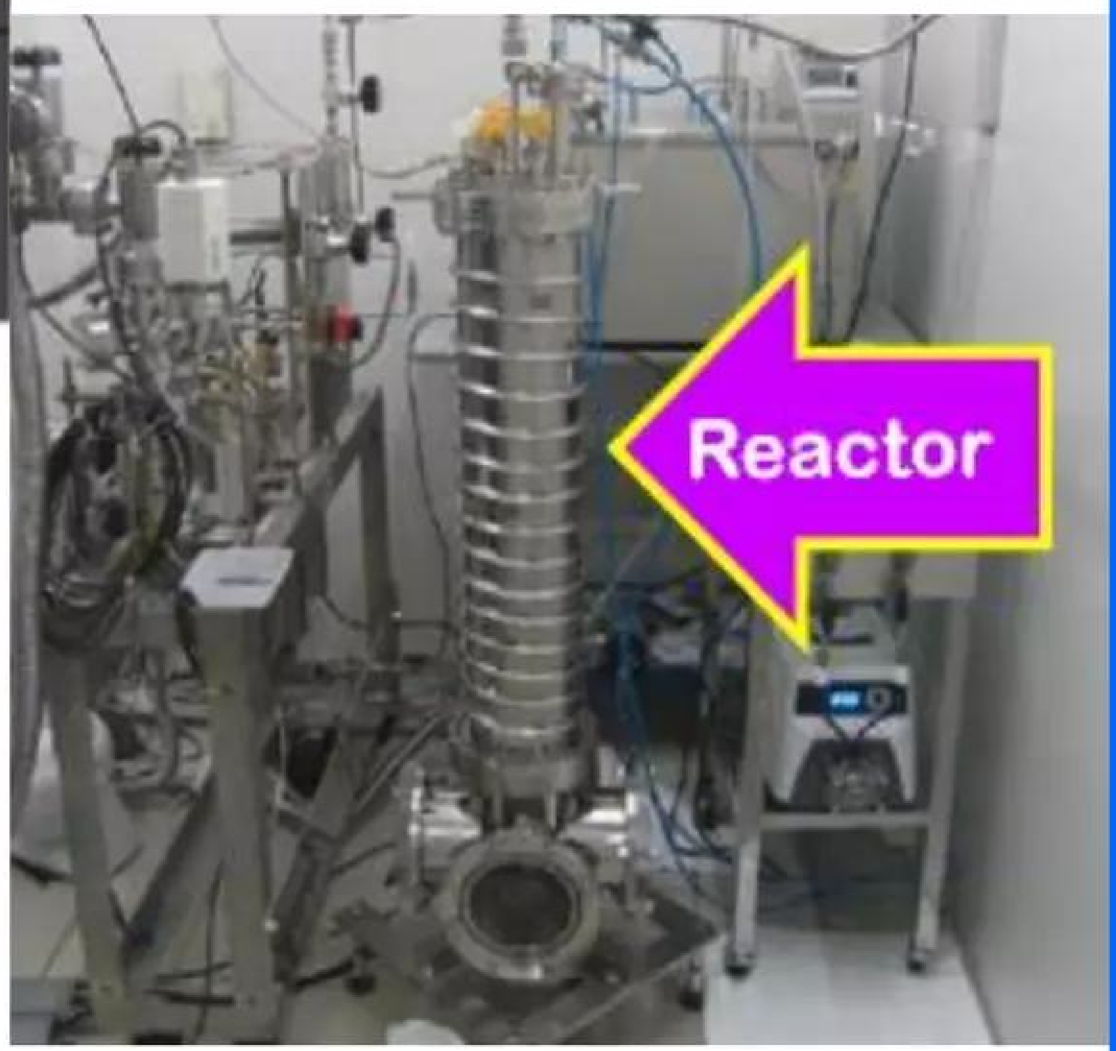
- Input energy is required to trigger LENRs: injection of input energy initiates far-from-equilibrium conditions that enable formation of nuclear-strength local E-fields which create populations of heavy-mass e^{-*} electrons in nascent LENR active sites. Heavy-enough e^{-*} are able to react directly with Q-M entangled p^+ or d^+ particles located in many-body active sites to produce catalytic ULE neutrons
- NEDO project LENR reactor vessels are resonant electromagnetic (E-M) cavities: energy input occurs by using external power source to heat-up reaction chambers (RC); this causes emission of broad-spectrum blackbody E-M radiation from inner walls of RC that irradiates nanoparticles found inside reactors. Surface plasmon electrons associated with surface nanostructures on "antenna" NPs will absorb incident E-M photon energy (e.g., at nanostructure IR resonant frequencies) and transport it to LENR active sites where ultralow energy neutrons are produced
- Relatively transparent to MeV gamma radiation, metal reactor walls are opaque to infrared (IR) radiation. When gamma conversion to IR occurs in LENR active sites, IR from down-converted gammas will be retained inside reactor cavity and be available to heat it up further. If energetic gain ratio in an LENR reactor is high enough, once it reaches required operating temperature range, external power could be turned-off; in theory, such reactors could continue to produce excess heat until key reactants are exhausted; in 1990s, poorly reproducible Italian Ni/H_2 gas experiments ran for up to 85 days and produced up to 900 MJ of excess heat

Input energy from blackbody infrared radiation inside reactor

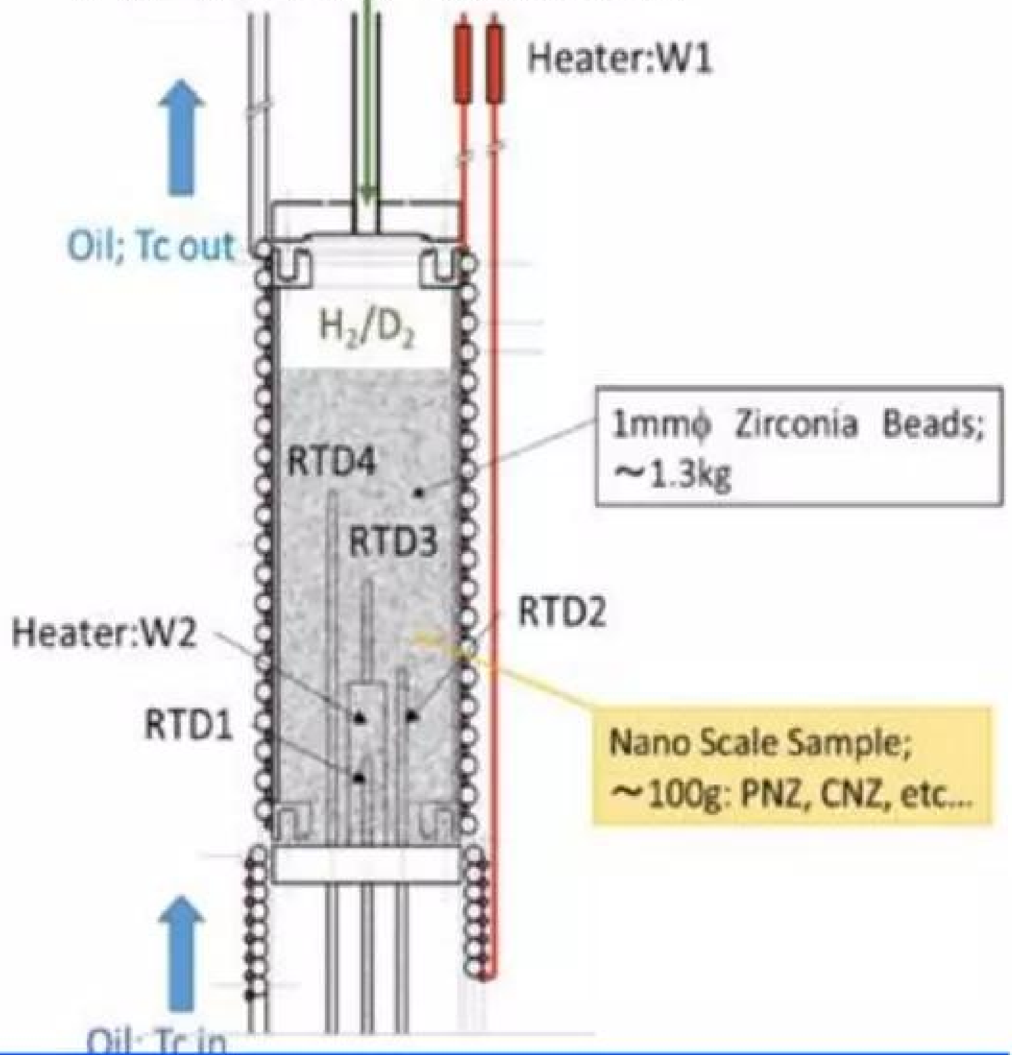
Power density of spectral peak for blackbody radiation changes with temp

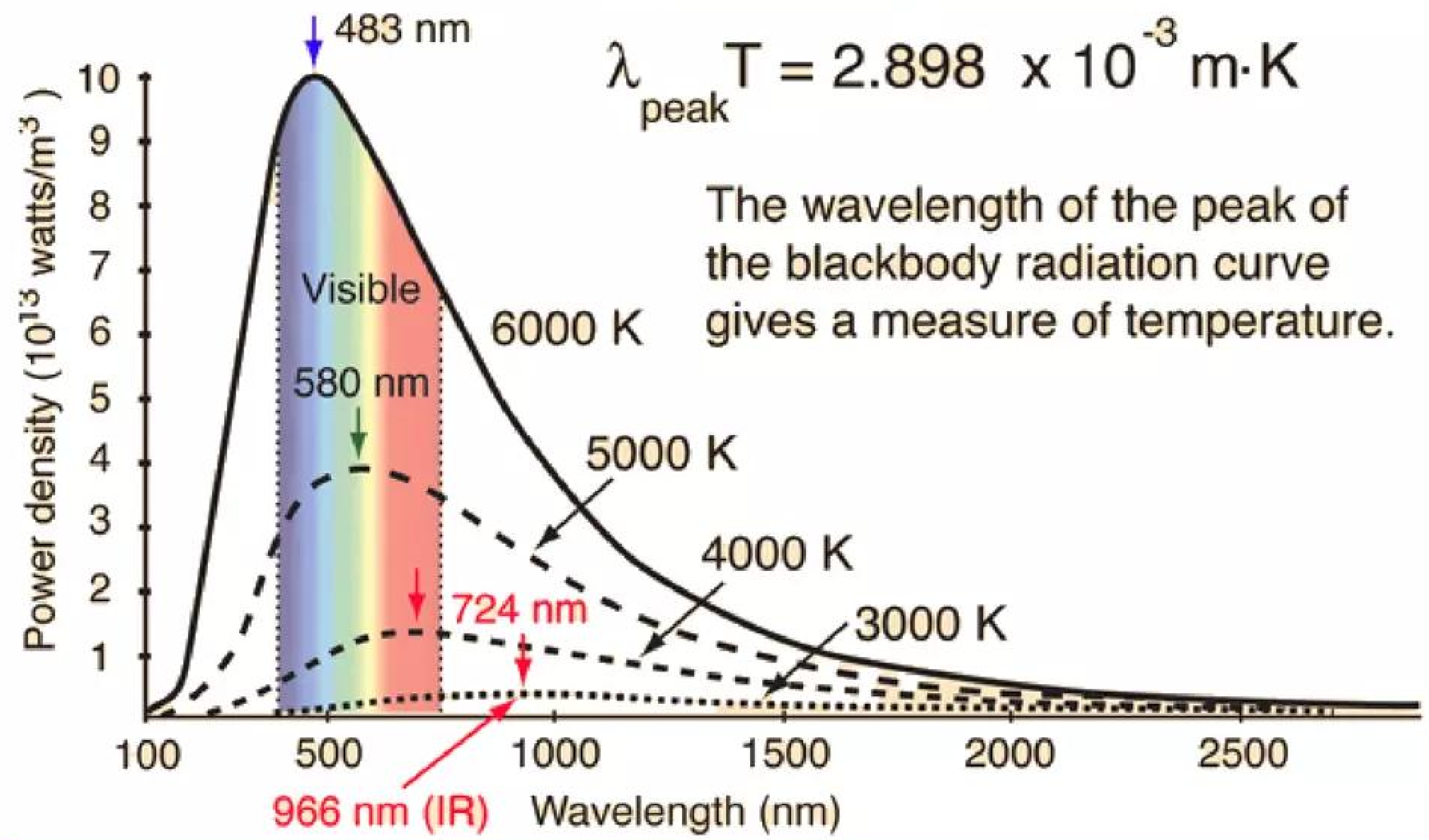


NEDO reactor



NEDO reactor





Zirconia (ZrO_2) absorbs photons in infrared parts of spectrum

1 mm ZrO_2 particles interact with 2 nm metallic NPs at/near contact points

“Solution phase synthesis of t-ZrO_2 nanoparticles in ZrO_2 - SiO_2 mixed oxide”

46 *J. Chandradass* et al.

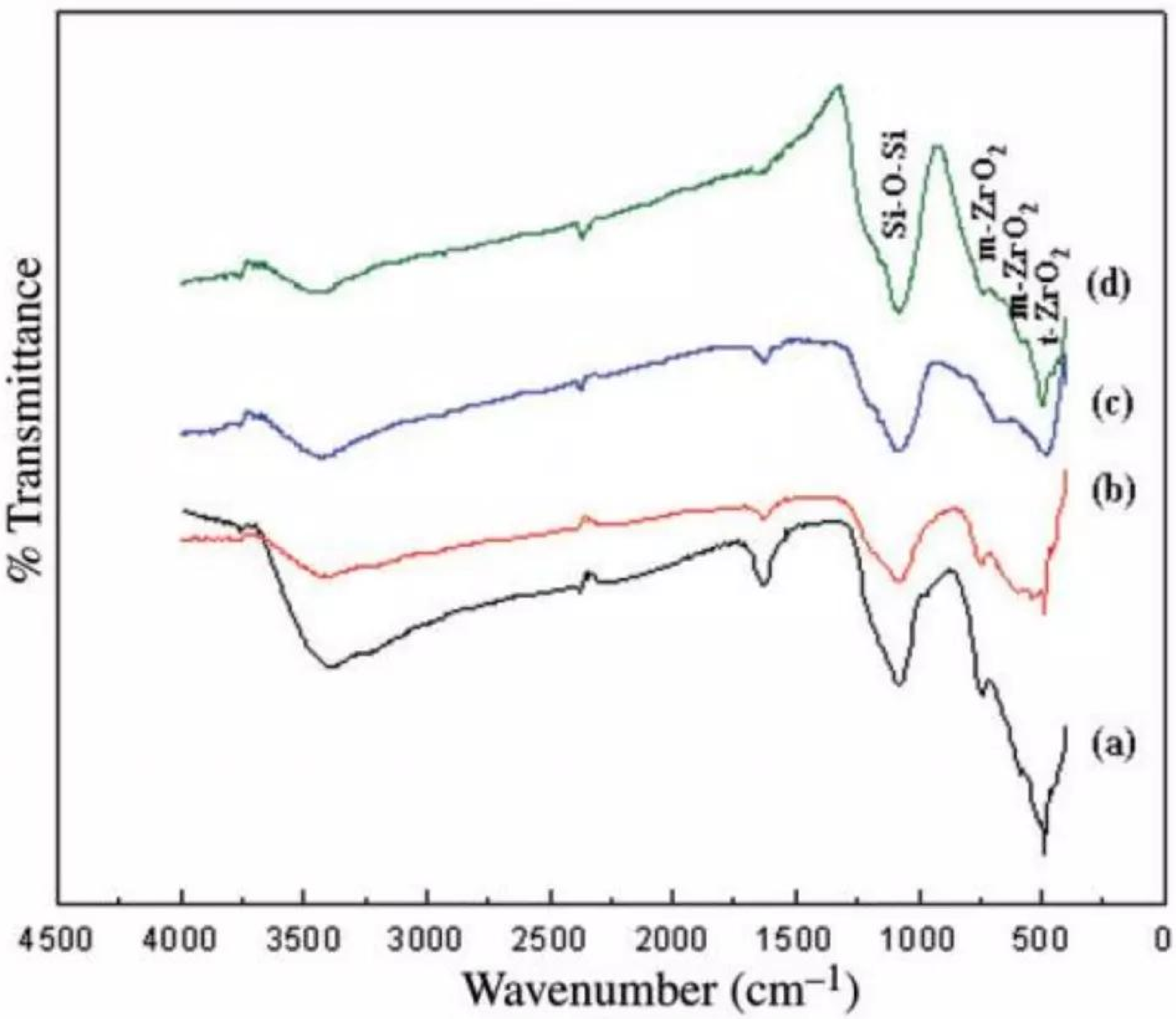


Figure 7. FTIR spectra of zirconia powder with 10 wt% silica calcined for 6 h (a) 600°C; (b) 800°C; (c) 1000°C and (d) 1200°C.

https://iom3.tandfonline.com/doi/pdf/10.1080/17458081003762813

Certain Nickel nanostructures can absorb infrared photons

Some metallic nanoparticle arrays have surface enhanced IR absorption

Large local electric field enhancements occur in close proximity to nanoparticles

"Surface-enhanced infrared absorption on elongated Nickel nanostructures"
D. Perry et al. *Journal of Physical Chemical Letters* 4 pp. 3945 - 3949 (2013)

Abstract: "There is a need for increasing the number of transition metals that can be used as substrates for surface-enhanced infrared absorption (SEIRA). We present here microscopy and infrared experiments that show oblique-angle deposition of Ni onto CaF_2 or BaF_2, which result in elongated Ni nanostructures (ENiNSs) that are partially aggregated and exhibit surface plasmon resonances in the mid-infrared. SEIRA enhancement factors in the range of 10–20-fold were observed for a monolayer of the *p*-nitrobenzoate ion adsorbed onto the ENiNS. Extending SEIRA to a metal such as Ni would yield different ways of studying Ni thin film and catalysis chemistry. This work also suggests that oblique-angle deposition might be used to create new SEIRA substrates from other metals."

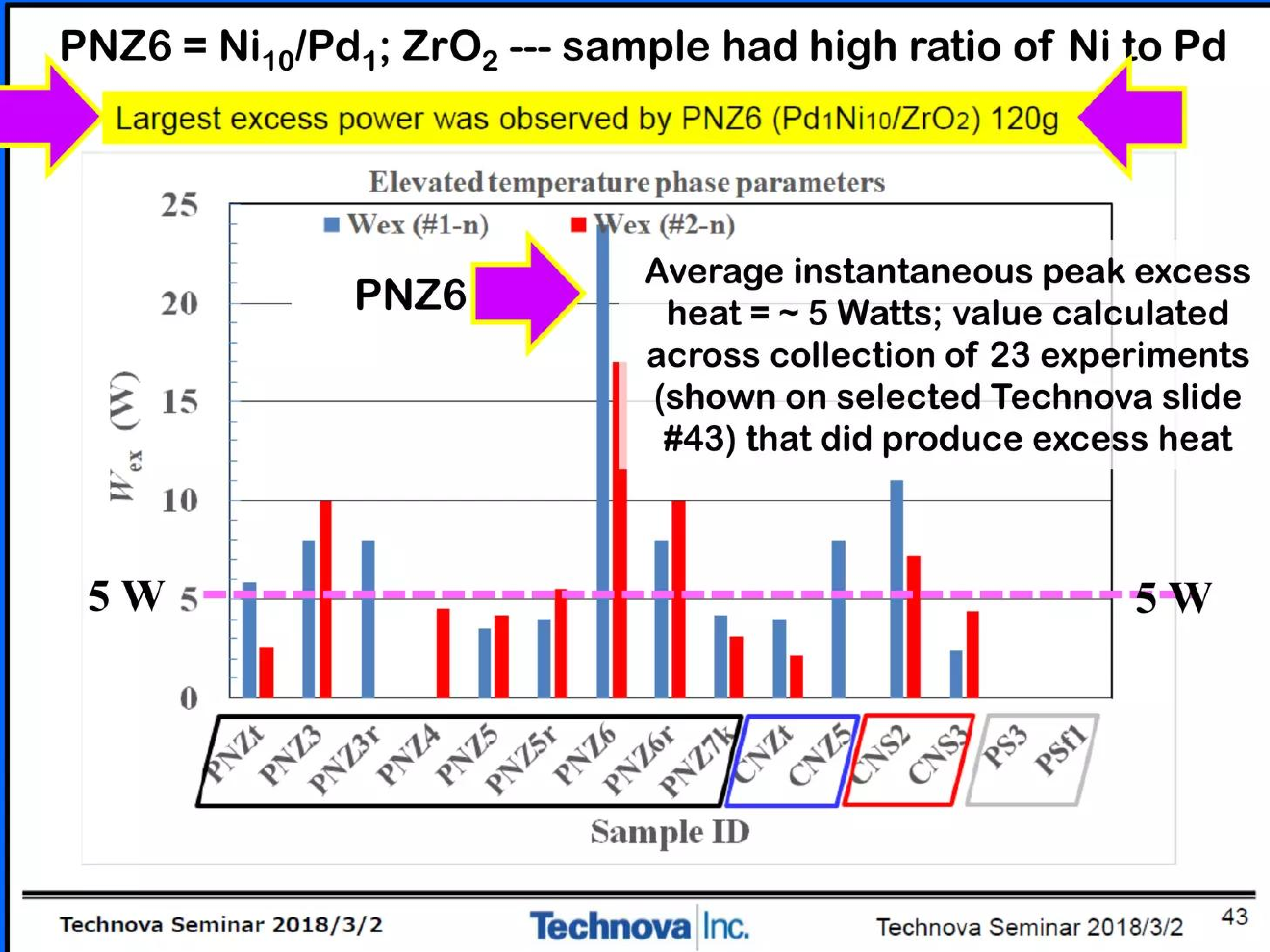
The Journal of Physical Chemistry Letters

https://pubs.acs.org/doi/abs/10.1021/jz402092y

NEDO LENR project experiments report Watts of excess heat

~77% of this experimental series produced an avg. ~ 5 Watts excess heat

PNZ6: 120 gms. of nanoparticles produced peak instantaneous power of 24 Watts

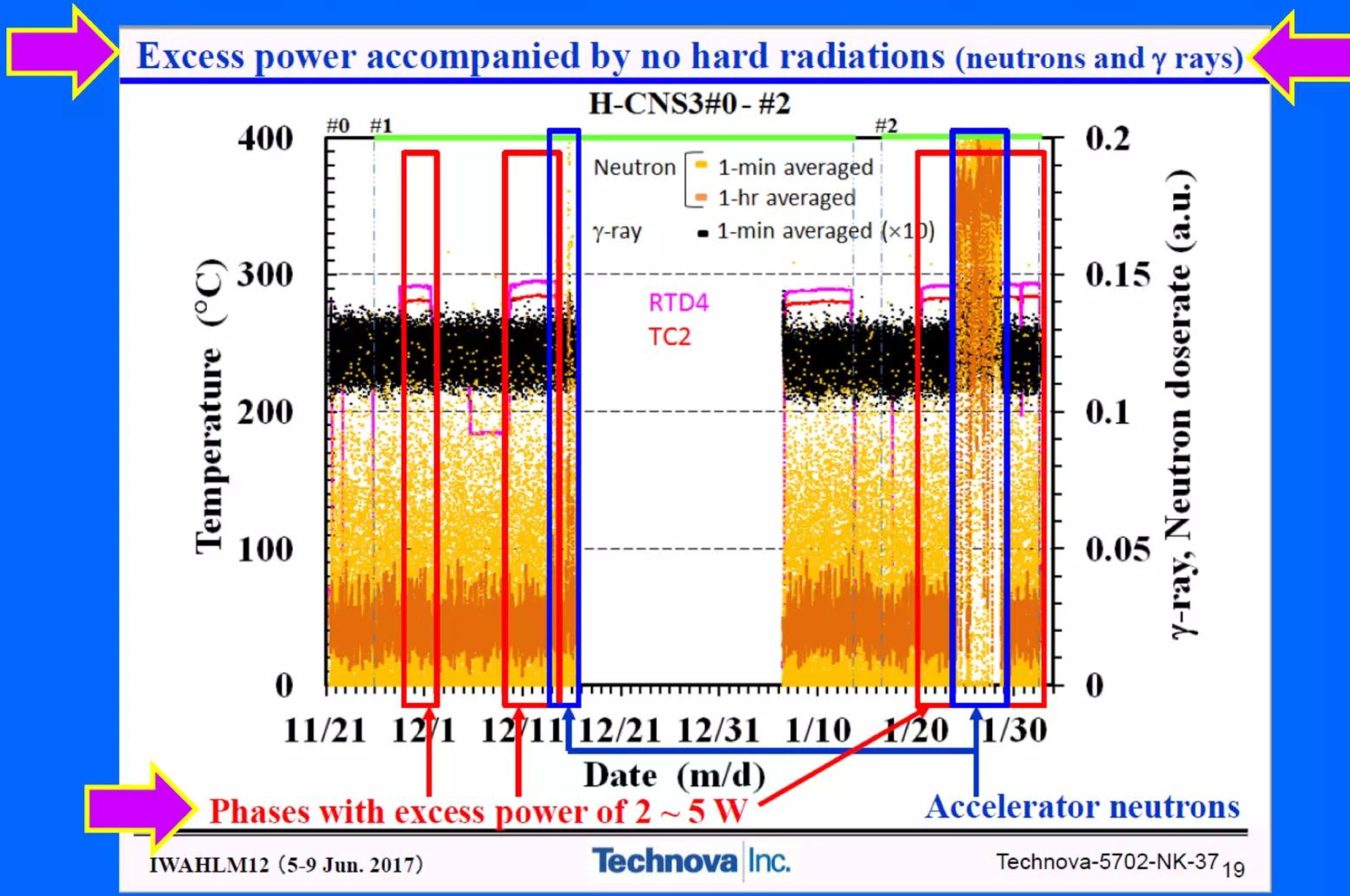


https://www.researchgate.net/publication/323600178_Present_Status_of_Cold_Fusion_Research

NEDO observed no emissions of neutron or gamma radiation

Unlike fission and fusion: no deadly radiation accompanies excess heat

Absence of energetic neutron or gamma radiation predicted by Widom-Larsen



https://www.researchgate.net/publication/317339283_Effect_of_Supporter_Material_on_Heat_Evolution_from_Ni-based_Nano-Composite_Samples_under_Exposure_to_Hydrogen_Isotope_Gas

NEDO results: Pd_xNi_x & Cu_xNi_x ‘fuel’ nanoparticles with ZrO_2

Monometallic nanoparticles did not produce excess heat; only bimetallic

ZrO_2 better metal-oxide vs. SiO_2: produces > excess heat per unit of fuel NP mass

Summary of cooperative exp. at Kobe, 2016~2017

ZrO_2-supported

(a) $Pd_{0.044}Ni_{0.31}Zr_{0.65}$; PNZ3, PNZ4, PNZ5

(b) $Cu_{0.044}Ni_{0.31}Zr_{0.65}$; CNZ5

SiO_2-supported

(c) $Cu_{0.008}Ni_{0.079}$ (mesoporous silica supported); CNS3

(d) Pd nanoparticles (mesoscopic SiO_2 supported); PSf1

- AHE at elevated temperatures around 300 °C were observed only for binary-metal nanoparticle samples ; no AHE for single-element-metal nanoparticles
- Observed both in D-Pd system and H-Ni system
- Excess power of 3 ~ 10 W for weeks at 200 ~ 300 °C
- Integrated released energy of 3 ~ 30 MJ/mol-Ni, or 4 ~ 90 MJ/mol-H
- ZrO_2 is advantageous as the supporter material, when compared in terms of excess energy per sample mass.
- Anyway, unexplainable by any known chemical reaction.

IWAHLM12 (5-9 Jun. 2017) Technova Inc. Technova-5702-NK-37 20

https://www.researchgate.net/publication/317339283_Effect_of_Supporter_Material_on_Heat_Evolution_from_Ni-based_Nano-Composite_Samples_under_Exposure_to_Hydrogen_Isotope_Gas

2017 NEDO results: PNZ Pd_xNi_x ‘fuel’ nanoparticles with ZrO_2

Fuel nanoparticles with higher Ni/Pd ratios produced greater excess heat

Quoting directly: “Pd/Ni ratio is one of the keys to increase the excess power”

Summary

Hydrogen isotope absorption and heat evolution have been examined for three kinds of ZrO_2-supported Pd·Ni nanocomposites, PNZ6, PNZ6r, and PNZ7k

- Excess power of 3~24W at elevated temperature of 200~300°C continued for several weeks.
- PNZ6 and PNZ6r samples with Pd/Ni=1/10 generated much higher excess power than PNZ7k with Pd/Ni=1/7 : Pd/Ni ratio is one of the keys to increase the excess power.
- Maximum specific energy η_{av} > 16 keV/D (1.6 GJ/mol-D), Integrated excess energy = 1 keV/Ni (100 MJ/mol-Ni)

Impossible to attribute to any chemical reaction, possibly radiation-free nuclear process

Technova Inc. 28

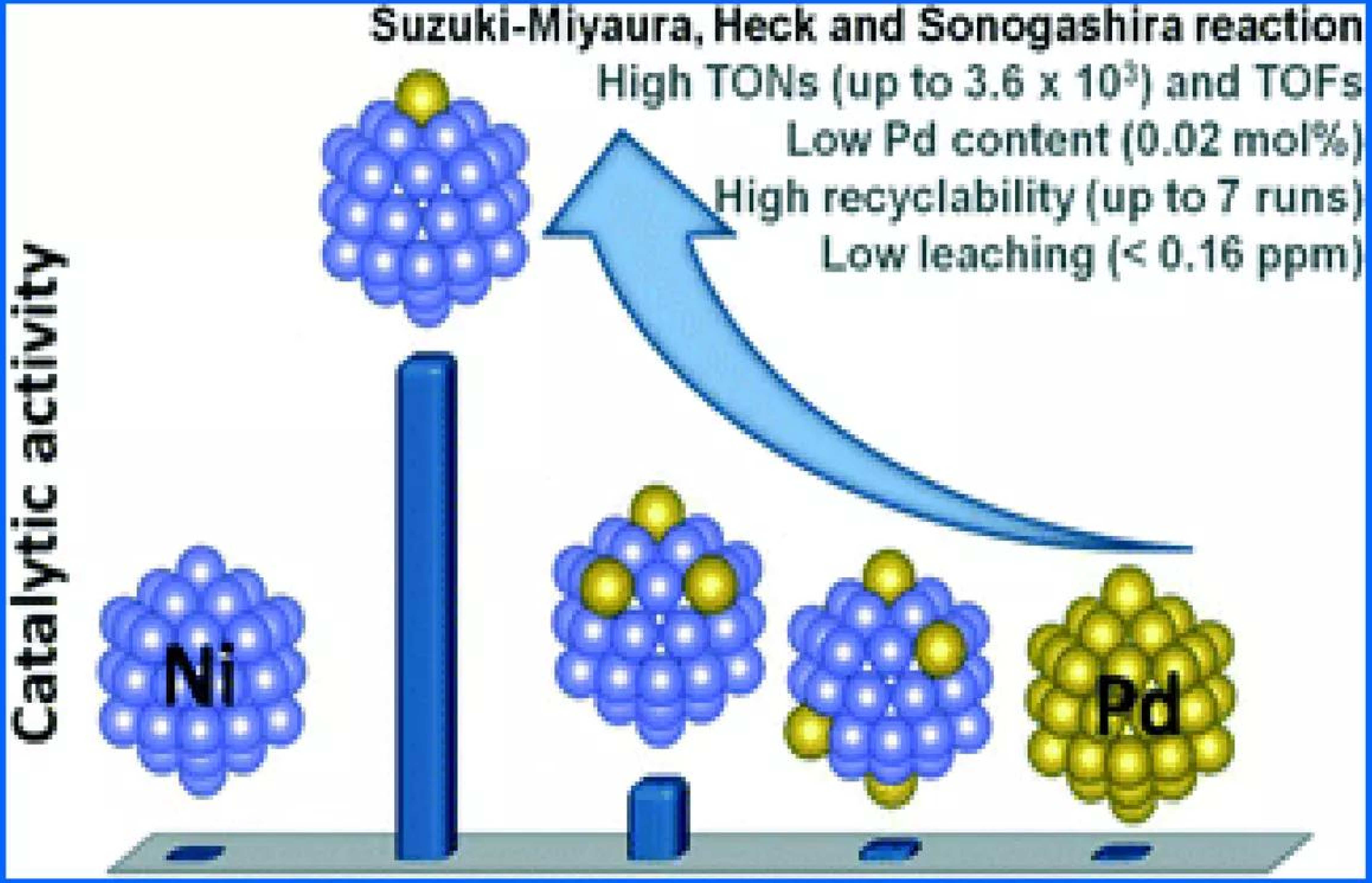
https://www.researchgate.net/publication/321295906_Comparison_of_excess_heat_evolution_from_zirconia-supported_Pd-Ni_nanocomposite_samples_with_different_PdNi_ratio_under_exposure_to_hydrogen_isotope_gases

Quite similar to results with NEDO Ni_xPd_x bimetallic catalysts

Pd or Ni NPs had little activity; activity increased with higher Ni/Pd ratios

Tested compositions for nanoparticles: Ni, $Ni_{0.99}Pd_{0.01}$, $Ni_{0.95}Pd_{0.05}$, $Ni_{0.90}Pd_{0.10}$, Pd

"Access to highly active Ni-Pd bimetallic nanoparticle catalysts for [Suzuki-Miyaura] C–C coupling reactions"
R. Rai et al. *Catalysis Science & Technology* 6 pp. 5567-5579 (2016)



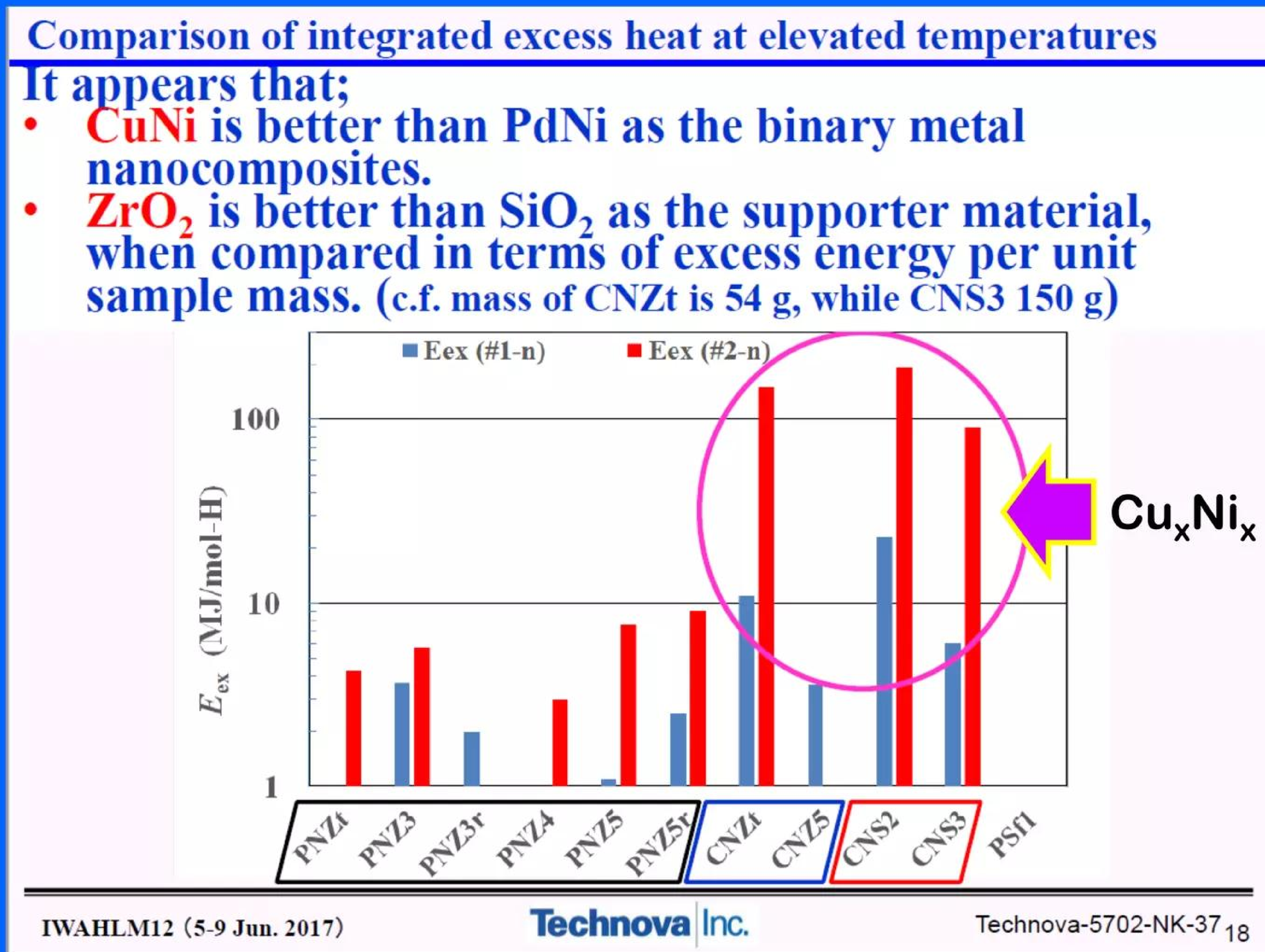
"In contrast to their monometallic counterparts, significantly enhanced catalytic activity was achieved with the studied Ni-Pd nanoparticle catalysts for the C–C coupling reactions, and products were obtained in moderate to high yields. The turnover number (TON) increases with the increase in the Ni to Pd atomic ratio for Ni-Pd nanoparticle catalysts."

https://pubs.rsc.org/en/content/articlelanding/2016/cy/c6cy00037a#!divAbstract

2017 NEDO results: Cu_xNi_x MJ/mol-H was larger than Pd_xNi_x

Reiterated conclusion that ZrO_2 was better than SiO_2 as support material

2018 NEDO experiment with Cu_7/Ni_1 sample CNZ7 showed spectacular excess heat



https://www.researchgate.net/publication/317339283_Effect_of_Supporter_Material_on_Heat_Evolution_from_Ni-based_Nano-Composite_Samples_under_Exposure_to_Hydrogen_Isotope_Gas

2018 NEDO result: instantaneous peak power was 130 Watts

High Ni to Cu ratio CNZ7 = Ni_7/Cu_1; ZrO_2 made 3 kilowatts for 100 seconds

Anomalous Heat Burst by CNZ7 Sample and H-Gas

Toyoshi Yokose[2], Akito Takahashi[1], Koh Takahashi[1], Yuichi Furuyama[2]

[1] Technova Inc., 100-0011 Japan,
[2]Graduate School of Maritime Sciences, Kobe University, 658-0022 Japan

Summary

- Anomalous heat burst with ca.130W peak power and ca. 365kJ was observed by CNZ7 sample under elevation of temperature. Heat pulse occurred in ca. 100s with ca. 3 kW peak power.
- It happened in the upper zone of RC when local H-absorption looked saturated.
- Strange oscillatory evolution of temperature was observed at gas-outlet/inlet point of RC, which may be same phenomena as Iwamura et al reported first at ICCF20.
- H-absorption at elevated temperature by CNZ7 is endothermic and has got near-saturation state in a few days.
- After saturation of H-absorption, sustaining excess power in earlier weeks was observed with 12-14W. Small hump with 19W excess was observed by re-filling H-gas of ca. 0.16 MPa into RC. (See Appendix-2)

To be presented at JCF19 Meeting, Nov. 9-10, 2018, Iwate University, Morioka, Japan

Yokose JCF19 22

https://www.researchgate.net/publication/328547673_Anomalous_Heat_Burst_by_CNZ7_Sample_and_H-Gas

Plasmonic antenna-reactor concept and NEDO CNZ7 result

Pd = catalytic reactor + proton reservoir; Cu = good plasmonic antenna

CNZ7 may have functioned as antenna-reactor complex per Swearer et al. (2016)

"Heterometallic antenna-reactor complexes for photocatalysis"
D. Swearer et al. *PNAS* 113 pp. 8916 - 8920 (2016)

Significance (quoting): "Plasmon-enhanced photocatalysis holds significant promise for controlling chemical reaction rates and outcomes. Unfortunately, traditional plasmonic metals have limited surface chemistry, while conventional catalysts are poor optical absorbers. By placing a catalytic reactor particle adjacent to a plasmonic antenna, the highly efficient and tunable light-harvesting capacities of plasmonic nanoparticles can be exploited to drastically increase absorption and hot-carrier generation in the reactor nanoparticles. We demonstrate this antenna–reactor concept by showing that plasmonic aluminum nanocrystal antennas decorated with small catalytic palladium reactor particles exhibit dramatically increased photocatalytic activity over their individual components. The modularity of this approach provides for independent control of chemical and light-harvesting properties and paves the way for the rational, predictive design of efficient plasmonic photocatalysts."

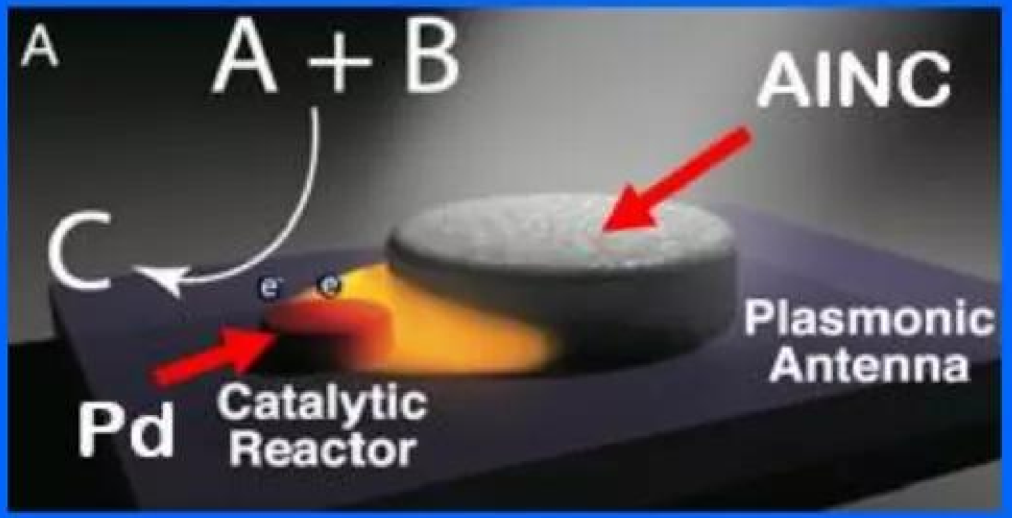
http://www.pnas.org/content/pnas/113/32/8916.full.pdf

Plasmonic antenna-reactor concept & 2018 NEDO CNZ7 NPs

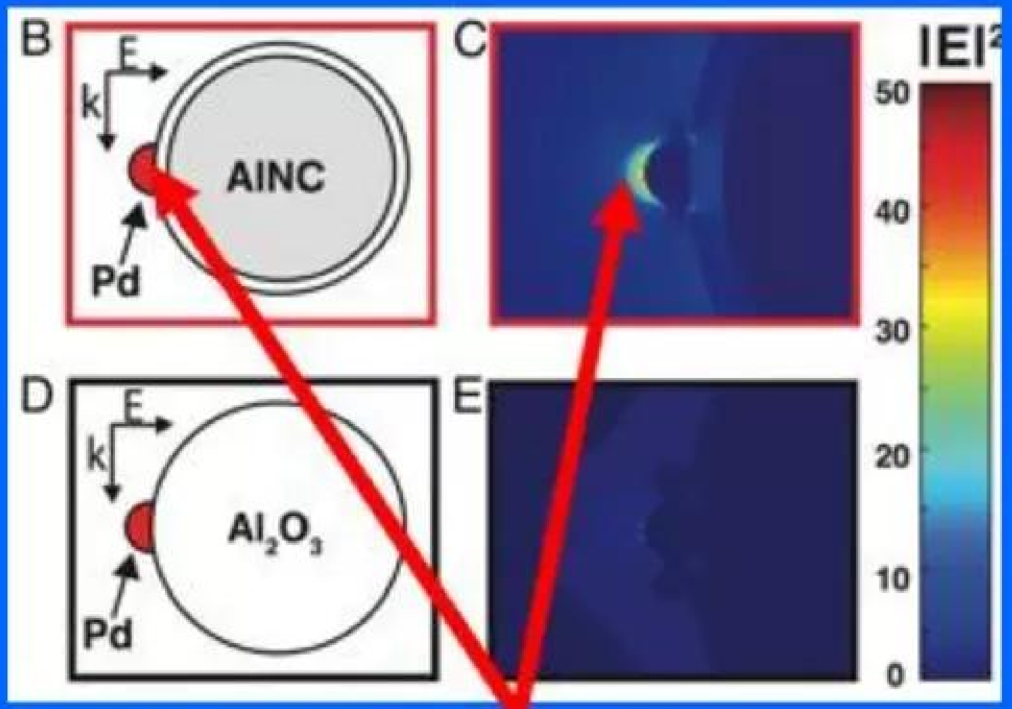
Are CNZ7 Ni_7/Cu_1; ZrO_2 NPs functioning like plasmonic antenna-reactors?

- Au, Ag, Cu, recently Al are generally considered to be superior plasmonic metals (good optical absorbers; a plasmonic "antenna"); whereas Pd, Ni, Pt, Rh, Ru, etc. are known to possess excellent catalytic performance but poorer plasmonic properties (nanotechnologists refer to this group of elements as catalytic "reactors")
- In plasmon-enhanced photocatalysis, new concept is to locate plasmonic antenna NPs in close proximity to catalytic reactor NPs; creates extremely synergistic "antenna-reactor" NP systems with greatly enhanced photocatalytic activity vs. well-separated components
- In NEDO experiments, Ni/Cu NPs, including 130 Watt 2018 CNZ7 result, were clearly observed to produce significantly greater excess heat than same-sized 2 nm Ni/Pd NPs. Assuming antenna-reactor concept is applicable to NEDO experiments, is very tempting to speculate that better performance of 2 nm Ni/Cu NP compositions might be attributed to fact that Cu/Ni effectively form an (antenna + reactor) system, while Pd/Ni does not conform to concept (reactor + reactor)

D. Swearer et al. (2016) Fig. 1 A.



D. Swearer et al. (2016) Fig. 1 B.



High E-fields between AlNC antenna and Pd catalytic reactor

Plasmonic catalysis' hot electrons analogous to e_n^{-*} in LENRs

LENR active sites also require charge-carrier localization & high EM fields

"Plasmon hot electron transport drives nano-localized chemistry"
E. Cortes et al. *Nature Communications* article number #14880 (2017)

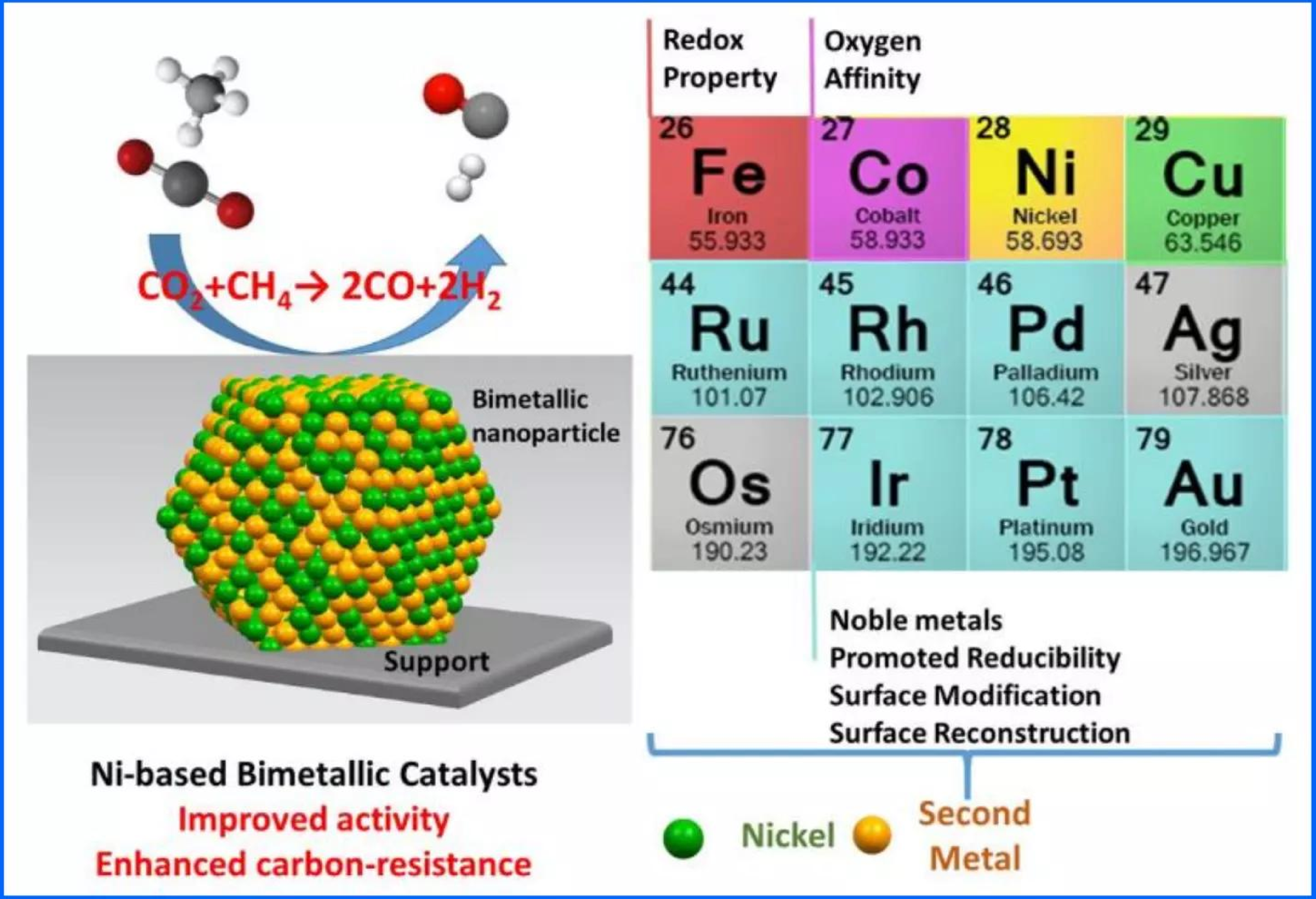
Quoting: "We have shown the ability to map a hot-electron reduction reaction on Ag nanoantennas with 15 nm spatial resolution and corroborated the spatially highly confined surface chemistry by first-principles calculations of hot carrier generation and transport. Our results progressively traced the reactivity in plasmonic antennas, highlighting strong dependence of the reactivity on the EM field distribution within the metal. Our theoretical treatment of plasmonic hot carrier generation and transport confirm nanoscale localization of high-density carrier regions required to drive this multi-electron chemical reaction and predict an inverse relation between collected carrier density and transport distance. Polarization-resolved experiments demonstrate that the high EM field intensities and the absorption of the nanoantennas are necessary to drive the reaction. Improved design of highly reactive and efficient antennas should benefit from these results. As we have shown, local surface chemistry can be tuned by employing this method, opening new possibilities for accessing regions of highly concentrated photon and electron densities. Positioning of nanomaterials or molecules in these regions is now possible and should boost research and applications in plasmonic hot-carrier science."

https://www.nature.com/articles/ncomms14880.pdf

Bimetallic Ni-based catalysts for CO_2 reforming of methane

"Presence of noble metal at surface with gas-induced surface reconstruction"

"A review on bimetallic Nickel-based catalysts for CO_2 reforming of Methane"
Z. Bian et al. *ChemPhysChem* 18 pp. 3117- 3134 (2017)



https://onlinelibrary.wiley.com/doi/epdf/10.1002/cphc.201700529

Chemical photocatalysis is actually closely related to LENRs

LENRs may have been triggered at Lanzhou Institute of Chemical Physics

"Toward a mechanistic understanding of plasmon-mediated photocatalysis"
Review article by J. Brooks et al. *Nanophotonics* 7 pp. 1697 - 1724 (2018)

Abstract: "One of the most exciting new developments in the plasmonic nanomaterials field is the discovery of their ability to mediate a number of photocatalytic reactions. Since the initial prediction of driving chemical reactions with plasmons in the 1980s, the field has rapidly expanded in recent years, demonstrating the ability of plasmons to drive chemical reactions, such as water splitting, ammonia generation, and CO_2 reduction, among many other examples. Unfortunately, the efficiencies of these processes are currently suboptimal for practical widespread applications. The limitations in recorded outputs can be linked to the current lack of a knowledge pertaining to mechanisms of the partitioning of plasmonic energy after photoexcitation. Providing a descriptive and quantitative mechanism of the processes involved in driving plasmon-induced photochemical reactions, starting at the initial plasmon excitation, followed by hot carrier generation, energy transfer, and thermal effects, is critical for the advancement of the field as a whole. Here, we provide a mechanistic perspective on plasmonic photocatalysis by reviewing select experimental approaches … To conclude, we evaluate several promising techniques for future applications in elucidating the mechanism of plasmon-mediated photocatalysis."

https://www.degruyter.com/view/j/nanoph.ahead-of-print/nanoph-2018-0073/nanoph-2018-0073.xml

Chinese chemists claimed photocatalytic triggering of LENRs

Produced Deuterium & Helium and transmuted Potassium into Calcium

Ultralow energy neutron reactions (LENRs)

Disruptive new source of safe, radiation-free nuclear energy

Experiments reported in 2017 by Prof. Gong-xuan Lu et al.
at Lanzhou Institute of Chemical Physics, in Lanzhou, China
showed photocatalytic triggering of LENRs at NTP with visible light

Lanzhou Institute of Chemical Physics,
Chinese Academy of Sciences

Very significant discovery if experimental
claims can be independently confirmed
by other researchers using same methods

Lewis Larsen
President and CEO
Lattice Energy LLC
June 30, 2018

Contact: 1-312-861-0115 Chicago, Illinois USA
lewisglarsen@gmail.com

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-chinese-chemists-report-photochemical-triggering-of-lenrs-at-ntp-in-aqueous-cells-by-irradiation-with-visible-light-june-30-2018

U.S. Navy has been quietly interested in LENRs since 1990s

Much more experience with U-235 fission technology than private sector

Proceedings of U.S. Naval Institute (USNI) published positive article about LENRs

Article begins by saying: "LENRs offer the first opportunity since the advent of fission reactors to change fundamentally the way the Navy powers its ships, systems, and weapons" **and goes on to say:**

"Once relevant LENR scientific and engineering parameters are more broadly understood and harnessed, LENR energy sources … could power underwater, surface, or airborne vehicles or stationary nodes."

And notes, "Since the European Organization for Nuclear Research (CERN) held a 2012 colloquium on LENRs, the prevailing explanation of the phenomenon has been the Widom-Larsen theory. Peer-reviewed experimental research reported in the *Japanese Journal of Applied Physics*, for example, has given support to this theory."

pdf copy of *Proceedings* article behind USNI website's paywall will be provided upon request

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-sept-2018-issue-proceedings-of-us-naval-insititute-published-9page-article-re-lenrs-as-disruptive-new-energy-technology-for-military-sept-3-2018

Three types of nuclear power: fission, fusion, and LENRs

Fission now used for propulsion in naval aircraft carriers & submarines

LENRs great improvement vs. fission & fusion: no deadly radiation or radwastes

TRL = technology readiness level   MeV = Megaelectron Volt = 1 million (10^6) eV

Heat producing nuclear process	Energetic MeV gamma γ radiation?	Energetic MeV neutron radiation?	Long-lived radioactive waste products?	Basic description of nuclear process which creates heat that can be harvested and converted	Energy release in MeVs Chemical only produces eVs
Fission: TRL 9^+ $Uranium^{235}$	Yes	Yes	Yes	Unstable heavy nuclei capture neutrons and shatter into fragments	~ 200 MeV complex mix of end-products
Fusion: TRL $4^{+\ 2018}$ ITER D+T reactor in $France^{2025}$	Yes All fusion	Yes For D+T	No Induced	Gigantic temperatures enable light ionized nuclei to smash together and then fuse into heavier chemical elements	Depending on specific fusion reaction, value ranges from ~ 3 to ~ 24 MeV
LENRs: TRL 4 In 2017, NEDO project had best-ever excess heat	No Heavy electrons convert γ into IR	No ~ All ULE neutrons captured locally	No Neutron-rich LENR products decay fast	Input energy creates ultra low energy neutrons (via $e + p$ reaction) that capture on target fuels. Gammas from neutron captures are converted into infrared; unstable products fast-decay into stable elements	Depending on fuels and subsequent reactions as well as decays, values range from ~ 0.1 MeV up to ~ 22 MeV

IR = infrared (heat)

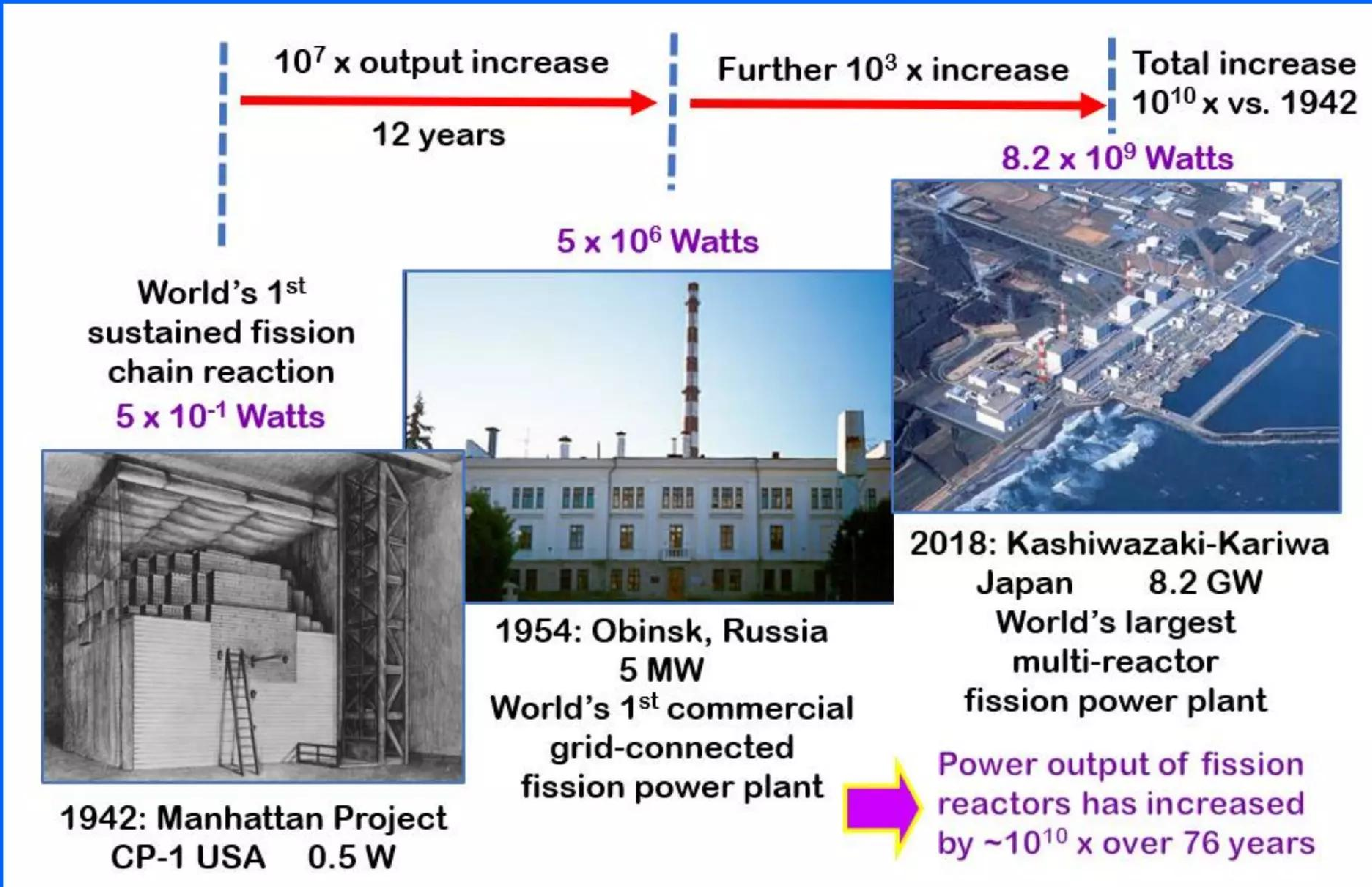
Likely that LENR system power outputs can be scaled-up

1942 - 2018: power output of fission reactors increased by factor of ~ 10^{10}

- Enrico Fermi's original Manhattan Project CP-1 Uranium fission reactor located at the University of Chicago in Illinois weighed ~ 400 tons and only produced 0.5 Watt (thermal) for 28 minutes went it first went critical back in 1942
- In 1954, USS Nautilus submarine launched with a 93% enriched ^{235}U pressurized water reactor that produced power output of ~ 10 megawatts (13,400 hp thermal); first fueling powered Nautilus until 1957, after voyaging 62,562 miles. In 1954, USSR opened world's first commercial nuclear power plant in Obinsk, Russia with total power output of 5 MW (net electrical) produced from 30 MW (thermal). Both of these early ^{235}U reactors were operational 12 years after CP-1
- Compared to CP-1, NEDO project devices at TRL-4 presently average ~ 5 Watts thermal and weigh about 100 grams; entire NEDO reactor system apparatus weighs < 1,500 pounds. Altogether, these facts argue that future commercial versions LENR power generation systems, which would not require any radiation shielding or containment subsystems, might eventually achieve higher effective system power densities than present-day commercial ^{235}U fission reactors
- Given programmatic funding at level of ITER (US$125 million/yr.), there is no a priori technical reason why thermal output of LENR power systems could not be scaled-up as rapidly as fission technology advanced from 1942- 1955 (10^7 times); μ-scale of discrete active sites suggests analogy to improvements in reducing sizes of electronic transistors that occurred from 1947 until today (> 10^6 times)

1942: "ugly" prototype of fission reactor became operational

CP-1 was 400 tons; first produced 0.5 Watts of excess heat for 28 minutes



1947: Bell Labs' "ugly" prototype of semiconductor transistor

First prototype fit on palm of hand --- transistors today are ~ 10^6 x smaller

LENR active sites akin to transistors in that they amplify input energy ("net gain")

William Shockley's explanation of transistor amplification for his students

Along with John Bardeen and Walter Brattain, he shared 1956 Nobel prize in physics for first invention of the semiconductor transistor in 1947

First 0.5" transistor prototype
1947 dimensions = ~ 1.3 x 10^7 nm

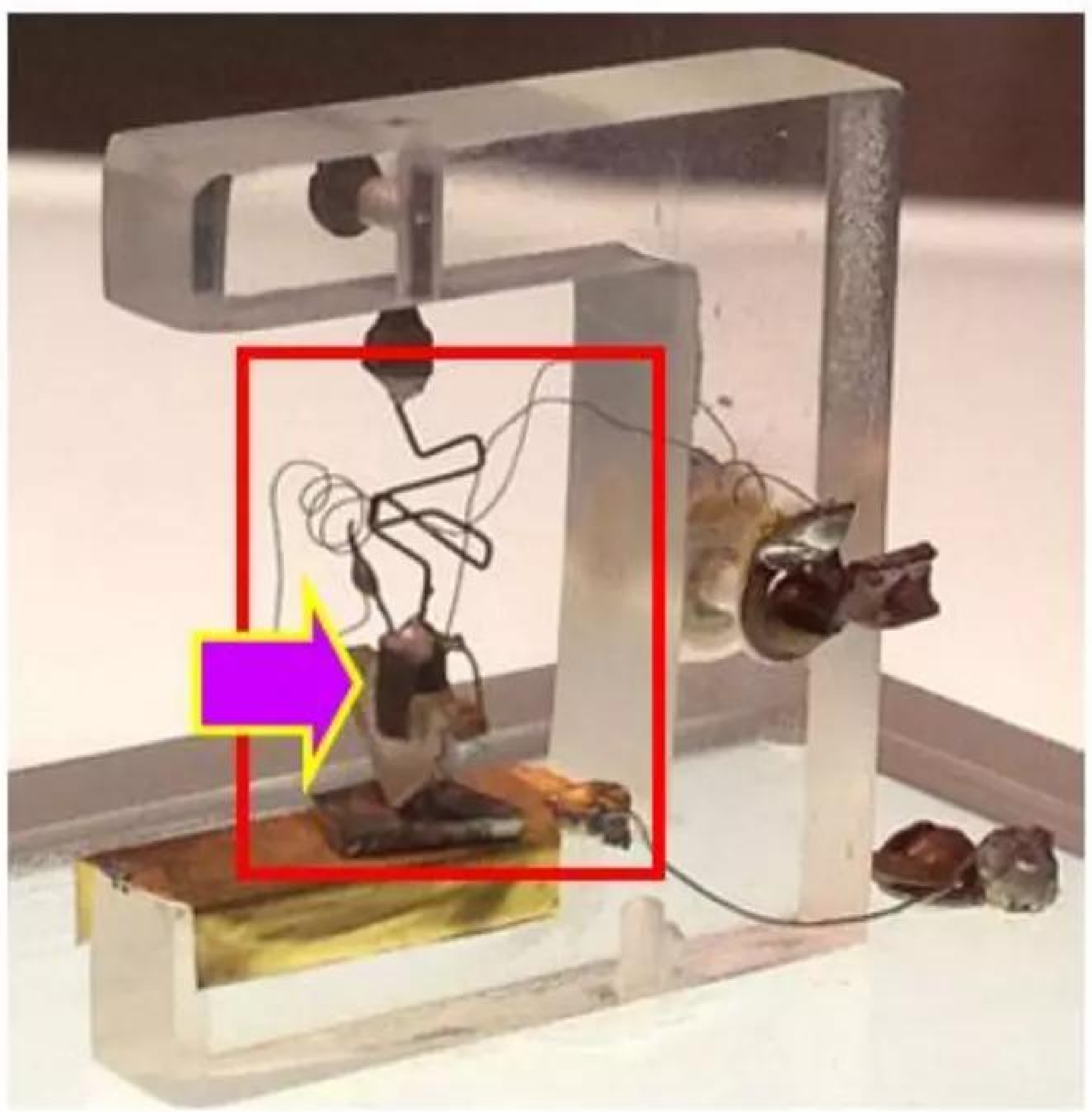


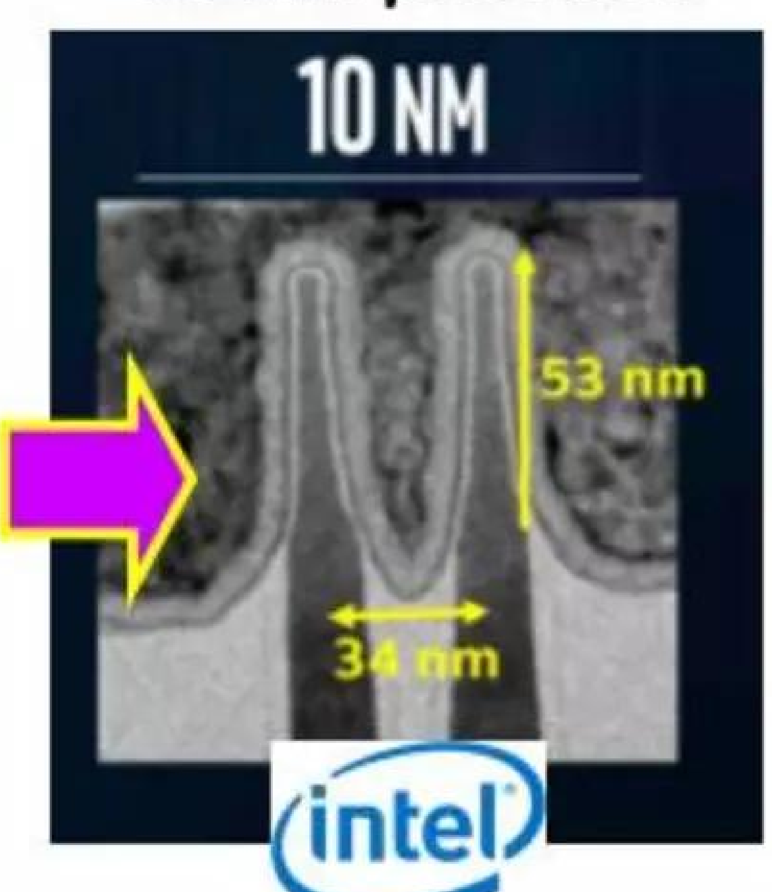
Photo credit: Bell Laboratories (1947)

"If you take a bale of hay and tie it to the tail of a mule and then strike a match and set the bale of hay on fire, and if you then compare the energy expended shortly thereafter by the mule with the energy expended by yourself in the striking of the match, you will understand the concept of amplification." W. Shockley

Dimensions of Intel's new transistors are ~2 million x smaller than back in 1947

2018: Intel's new Cannon Lake processor chips are their first-built on a 10 nm manufacturing process. Transistor fin pitch is 34 nm; fin height only 53 nm.

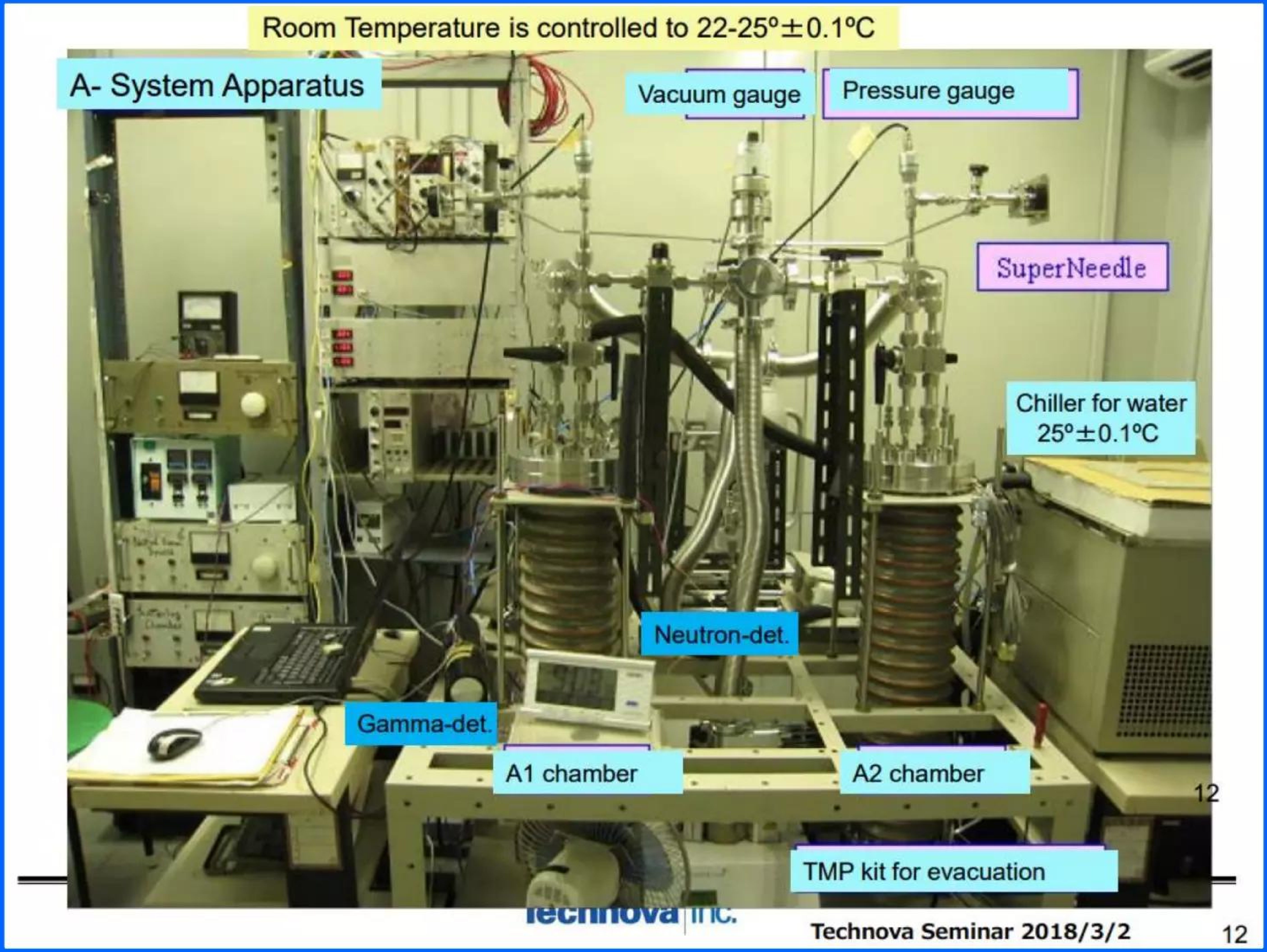
10 nm process



2018: NEDO project's LENR reactors are "ugly" prototypes

Unshielded reactors produce Watts of excess heat without any radiation

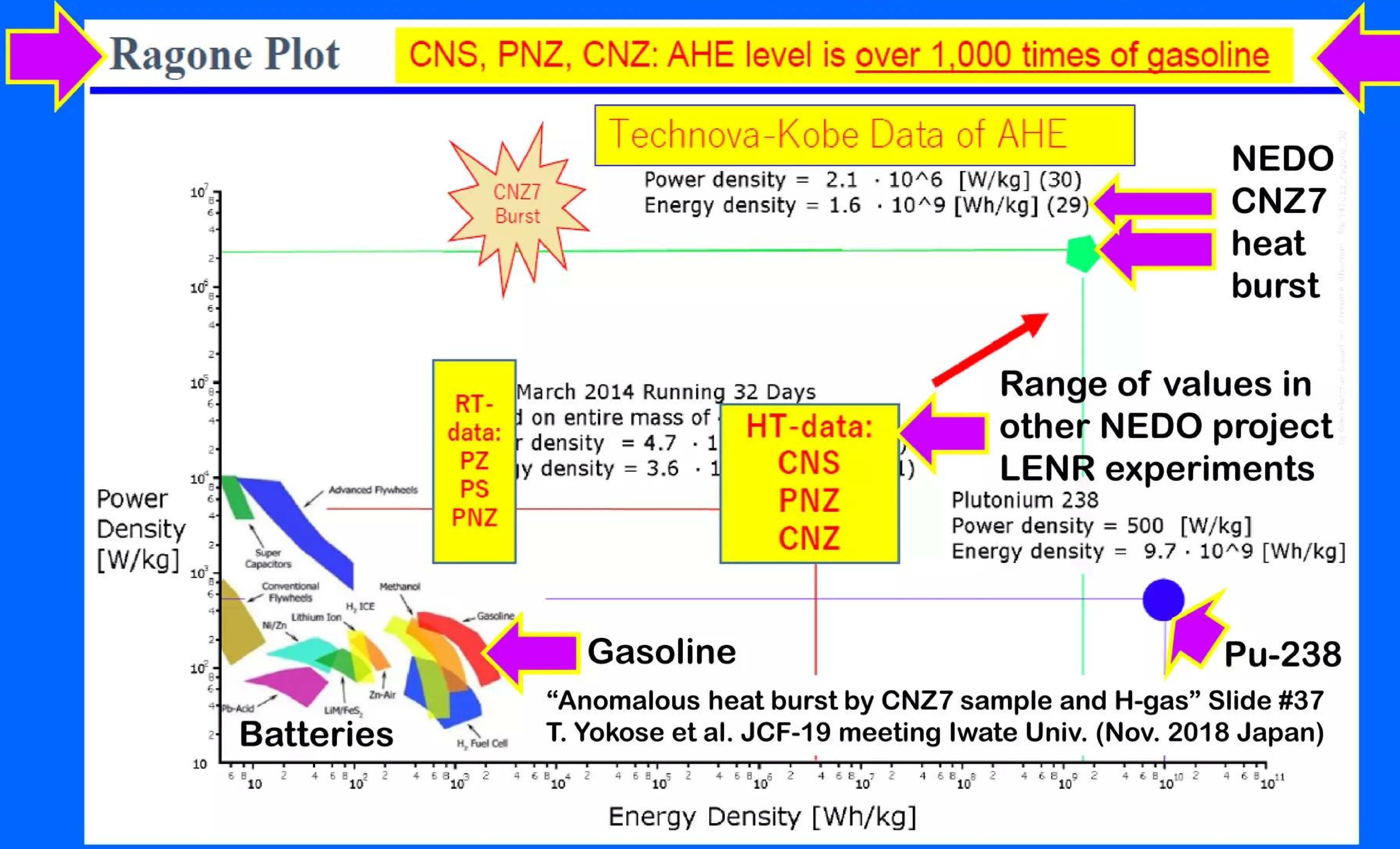
2014 - 2018: NEDO researchers increased LENR device thermal output by > 10^3 x



NEDO LENR device energy densities now at 1,000x > gasoline

Device CNZ7 Ni_7/Cu_1 ; ZrO_2 ; H_2 heat burst energy density = 1.6 x 10^9 Wh/kg

Future LENR fuel nanoparticles could have energy densities 5,000x > vs. gasoline



https://www.researchgate.net/publication/328547673_Anomalous_Heat_Burst_by_CNZ7_Sample_and_H-Gas

Nanoparticulate LENR fuels could be used in many systems

Possible LENR target fuels include: Nickel, Lithium & aromatic Carbon

Commercial LENR fuel energy densities could be > 5,000x larger vs. gasoline

- High energy density: motor vehicles, aircraft, or very small ships powered by LENRs could travel around entire world on quantity of nanoparticulate fuel that would fit into 2 large FedEx boxes. LENR fuels would be inert and benign and could utilize overnight package delivery systems or UAVs for resupply
- Size of fuel logistics pipelines would collapse: typical gasoline or diesel tanker trucks as shown below carry ~ 5,000 to 12,000 US Gallons of liquid fuel. LENR fuels producing same # of BTUs could fit into 1 or 2 FedEx boxes

Radiation-free ultralow energy neutron reactions (LENRs)

Absence of radiation and radwaste = game-changing energy technology

Greenness should make LENR power systems vastly less expensive than fission

- **Unlike nuclear fission and fusion:** heat-producing LENRs do not emit any deadly energetic 'hard' gamma and neutron radiation or make hazardous long-lived radioactive wastes
- **Consequence:** future LENR power generation systems would not require heavy, expensive radiation shielding and containment subsystems for safe long-duration operation
- **Enables:** LENR-based power systems to be vastly smaller and less expensive than fission or fusion reactors as well as light-enough to be safely utilized in unshielded propulsion systems for vehicles, aircraft, watercraft, and spacecraft
- **Enables:** eventual development of small, portable LENR power systems that would be safe, disposable after use in direct competition with chemical batteries and fuel cells

LENR power & propulsion boost range/endurance 10x - 100x

Examples assume no speed increases: show impact on range/endurance

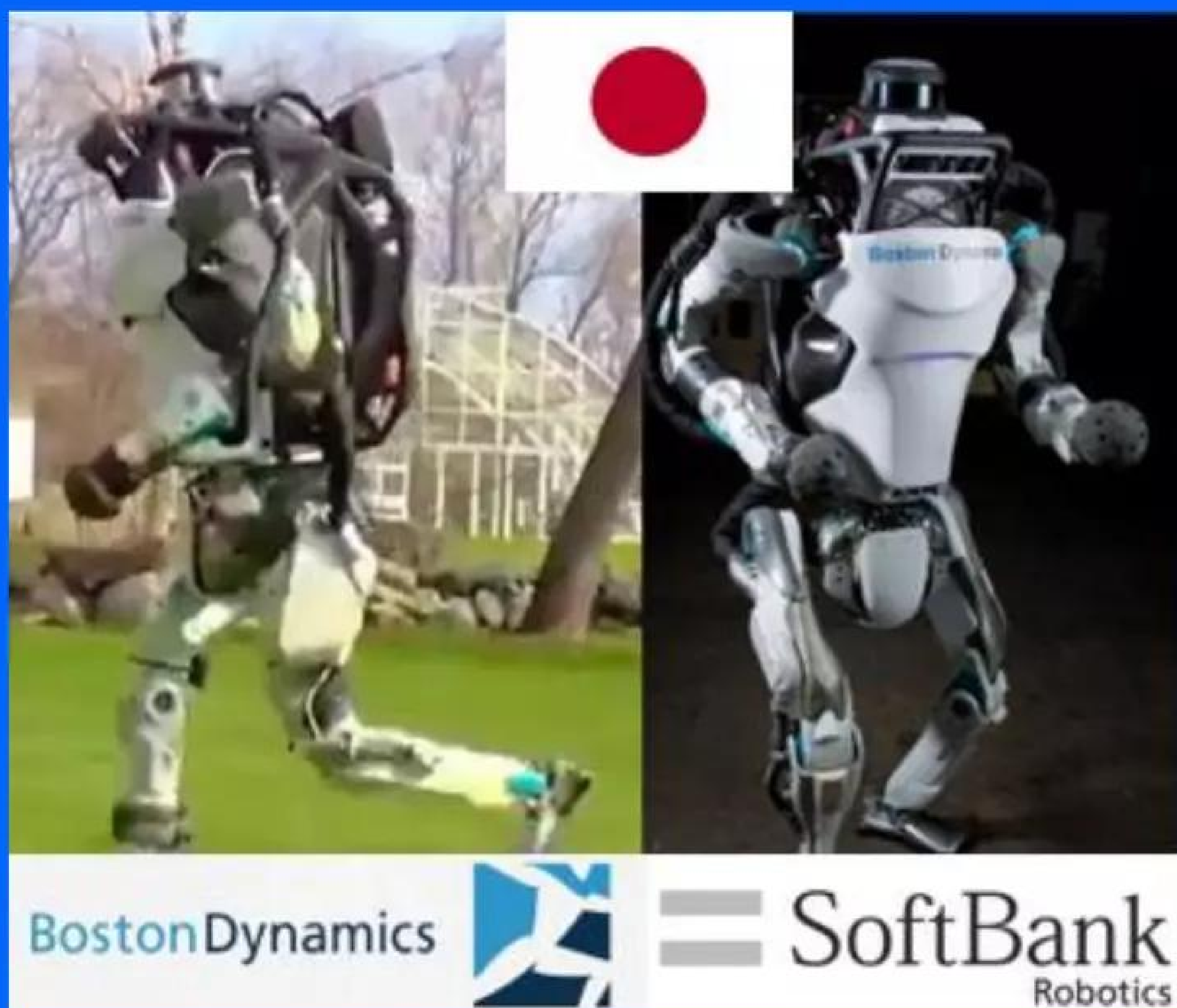
Systems	Present capabilities with today's battery and combustion-based power & propulsion technologies	Range/endurance enhancement with future LENR power systems	
		10x chemical	100x chemical
Insectoid recon bots and "slaughterbots"	Science fiction today … but tomorrow ???	24 - 48 hours ???	days to months ???
Yuneec Typhoon H920 Plus (China)	State-of-the-art commercial hexacopter 12.4 miles: 24 minutes @ 31 mph cruise	124 m (4 hrs. @ 31 mph cruise)	1,240 m (40 hrs. @ 31 mph cruise)
Predator MQ-1 drone General Atomics (US)	24 hours @ max 135 mph (est. 84 cruise) Discrepancy - mfgr. says range 770 miles	7,700 m (~ 3.8 days @ 84 mph cruise)	77,000 m (~ 38 days @ 84 mph cruise)
Super Heron drone (Israeli Aircraft Ind.)	45 hours @ max 173 mph (est. 121 cruise) Discrepancy - mfgr. says range 621 miles	6,210 m (~ 2.1 days @ 121 mph cruise)	62,100 m (~ 21 days @ 121 mph cruise)
Tesla Model S (2018)	Typical ~ 335 miles: 4 - 5 hours @ 70 mph	3,350 m (50 hrs.)	33,500 m (500 hrs.)
Bluefin-21 drone (US)	75 nautical miles: 25 hours @ 3 knots (GD)	750 nm (10.4 days)	7,500 nm (104 days)
Mark- 48 torpedo (US)	31 nautical miles: 33 min. @ 56 knots	310 nm (5.5 hrs.)	3,100 nm (55 hrs.)
"Khishchnik" torpedo (supercav. - Russia)	70 nautical miles: < 21 min. @ > 200 knots "Elektropribor" (G. Savchenko est., 2017)	700 nm (3.5 hrs. @ 200 knots cruise)	7,000 nm (35 hrs. @ 200 knots cruise)
Exoskeletons and combat "power suits"	Present batteries severely limit endurance without access to external power sources	Duration of autonomous activity could be increased up to a week or even months	
Autonomous biomech military robots	Present batteries severely limit endurance without access to external power sources	Duration of autonomous activity could be increased up to a week or even months	

LENR power would enable autonomous robots/exoskeletons

Military exoskeletons require 3 - 15 kW of onboard power for > 48 hours

Energy density of battery technology cannot provide militarily useful endurance

2018: 3.7 kWh Li-ion battery lasts 1 hr.   **Future:** LENR powered exoskeletons & combat suits



Video of BD "Atlas" robot jogging:
https://www.youtube.com/watch?v=g3qi-L5GPSM

March 2018:
https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=9ba5618073c7bfa2d4abd42e1f5c4ee4

Newsweek "Russia has developed Titanium exoskeleton for future wars --- but it has one problem" by Damien Sharkov *Newsweek* Dec. 15, 2017

Semyonov said: "However, the matter of creating such a battery is not solved anywhere in the world. This is a shared problem." [needs capable power source!]

http://www.newsweek.com/russia-has-made-titanium-exoskeleton-future-wars-it-has-one-problem-749569

LENR fuel energy density: massive impact on aircraft design

FedEx box of fuel could power SR-71 mission; cut fuel fraction by 90%

50 - 100 MW LENR propulsion systems needed to power larger aircraft, cruise missiles, and ships: energy densities of LENR fuels would be 5,000x > gasoline

LOCKHEED MARTIN

SR-71 Blackbird carried ~12,000 gallons of JP-7 aviation fuel with full tanks; permitted unrefueled range of 3,250 miles flying @ Mach 3 (2,284 mph)

Fuel fraction = onboard fuel as % of an aircraft's total weight at takeoff:

Ford F-150 truck only 3%

Boeing 737-600 27%
F-22 Raptor 29%
Predator MQ-1 drone 30%
Eurofighter 31%
F-35 Lightning JSF 33%
Airbus A380 44%
Mig-31 Foxhound 45%
Concorde SST 50%
B2 Spirit bomber 50%
SR-71 Blackbird 65%
Rutan Voyager 72%
V.A. GlobalFlyer 83%

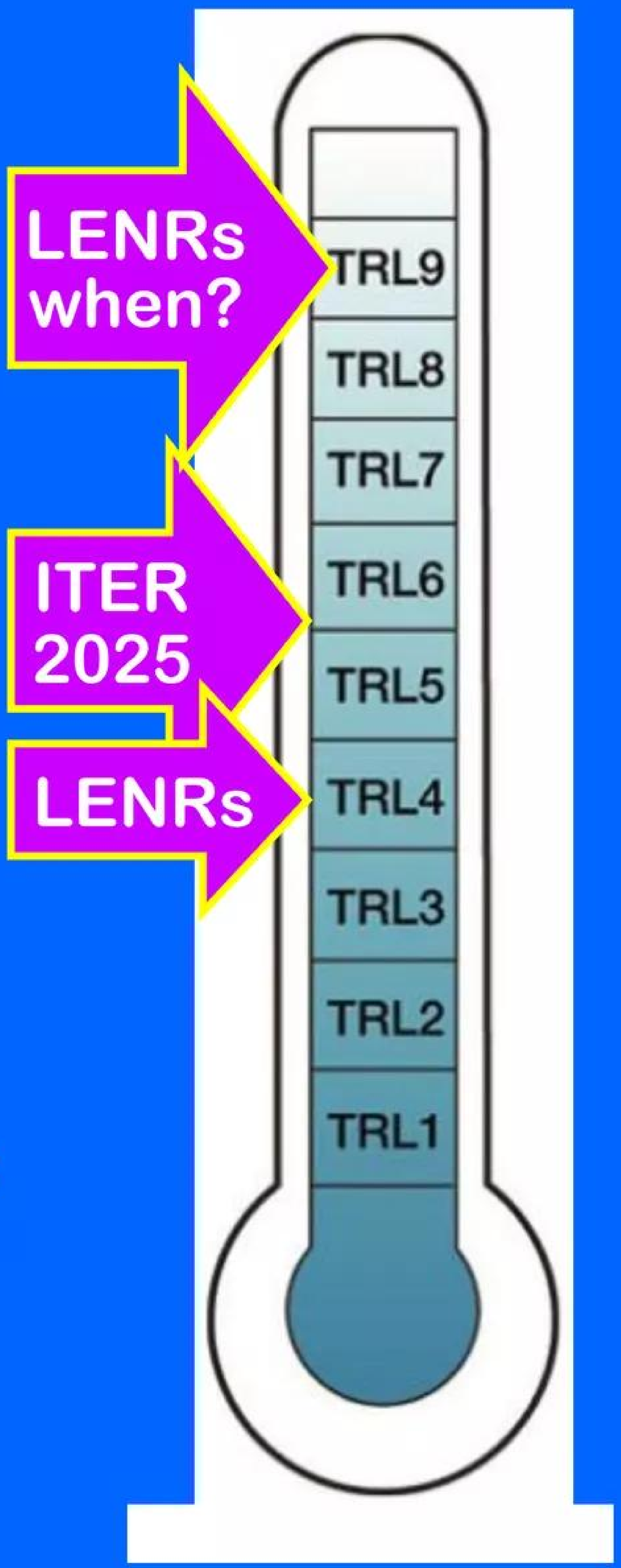
Missiles (typical) > 85%
Saturn-5 (moon) 96%

Large increases in R&D spending on LENRs are warranted

LENR technology at TRL-4; spend > $US 1 billion to hit TRL-9 reasonable

- Over 26 years prior to funding of NEDO's LENR project, total cumulative worldwide R&D spent on LENRs was at the most ~ US$250 million; LENRs nevertheless advanced up to TRL-3
- In three years since 2015, cumulative NEDO LENR project spending probably was at most US$ 54 million; its reported results have advanced LENR development to TRL-4. Today, total number of scientists working full-time on R&D in LENR technology is probably < 200 people worldwide. Total R&D funding since 1989 thus likely < US$ 300 million worldwide
- Given that LENRs are now at TRL-4 and technology's huge intrinsic advantages vs. fission & fusion reactions for power generation, large increases in R&D spending are warranted. Present R&D is ridiculously underfunded given future potential
- By comparison, Sagara et al. (2015) believe that successful operation of the ITER D+T fusion demonstration reactor in 2025 would only advance D+T fusion power technology to TRL-5/6 after cumulative spending of > US$ 22 billion on ITER alone

http://www-naweb.iaea.org/napc/physics/meetings/TM49530/website/talks/May%2012%20Sessions/Sagara_A.pdf



Further info about Japanese NEDO project's reported results

Purplish hyperlinks below are live as well as elsewhere in this PowerPoint

"Commercialization of radiation-free LENRs for power generation could occur with surprising speed: after stagnating at TRL-3 for 10$^+$ years Japanese industry-academic consortium including Mitsubishi Heavy Industries, Toyota, and Nissan Motor Company, achieved TRL-4 in 2.5 years and spent less than US$54 million"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-revolutionary-lenrs-for-power-generation-accelerating-development-path-from-present-trl4-to-trl9-april-9-2018

"Japan's NEDO LENR device fabrication and testing project achieved key technological milestones – more data released in Technova seminar on March 2"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-march-2-technova-seminar-in-tokyo-released-more-info-re-nedo-lenr-device-project-march-12-2018

"Small, primitive nanocomposite LENR devices fabricated in NEDO project produced enough cumulative excess heat to boil cup of tea for up to 45 days"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-industryacademiagovernment-project-nanocomposite-lenr-devices-produce-enough-heat-to-boil-cup-of-tea-feb-7-2018

"Japan's NEDO industry-academia-government R&D program's recent experimental results technically validated potential for LENRs to become major future energy source"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-lenr-project-reported-reasonably-reproducible-wattlevel-excess-heat-production-feb-4-2018

Key publications about Widom-Larsen theory of LENRs

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)
http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
Pramana - Journal of Physics 75 pp. 617 - 637 (March 2010)
http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen
Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)
http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"Hacking the Atom" (Volume 1 - 484 pages) popular science book
Steven B. Krivit, Pacific Oaks Press, San Rafael, CA, September 11, 2016
Paperback US$16.00; hardcover US$48.00; Kindle US$3.99
https://www.amazon.com/dp/0996886451

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L. Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

- We believe Lattice is the world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our published peer-reviewed theoretical papers rigorously explain the breakthrough device physics of LENR processes, including the absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production
- Lattice welcomes inquiries from large, established organizations that have an interest in discussing the possibility of becoming Lattice's strategic capital and/or technology development partner
- Lewis Larsen also independently engages in consulting on variety of subject areas that include: Lithium-ion battery safety issues; long-term electricity grid reliability and resilience; and evaluating potential future impact of LENRs from a long-term investment risk management perspective for large CAPEX projects in the oil & gas, petrochemicals, transportation, utility, and aerospace industries

