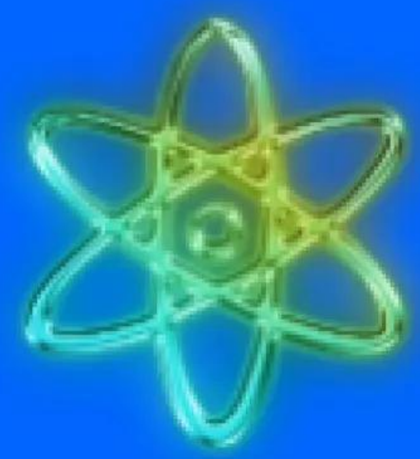
Lattice Energy LLC

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

Commercialization of LENRs for power generation could potentially occur with surprising speed

NEDO-funded LENR device project achieves TRL-4 and validates application of Widom-Larsen theory and nanotech to accelerate development pathway to commercialization at TRL-9

Those wishing to skip introductory information about NEDO and LENRs: go directly to Slide #18



Lattice, Mitsubishi Heavy Industries, Toyota, and Nissan are all developing new type of nuclear power generation technology that could be vastly better than fission or fusion because it would be hard-radiation-free and produce negligible long-lived radioactive wastes. Although presently at early TRL-4 stage of technological development, ultralow energy neutron reactions (LENRs) offer great promise as a new future source of affordable CO_2-free green energy.

Comparison of LENRs to fission and fusion

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (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; major radioactive waste clean-up issues and costs; limited sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development; heavy element U-235 (fissile isotope fuel) + neutrons → complex array of lower-mass fission products (some are very long-lived radioisotopes) + energetic gamma γ 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) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle γ and 14 MeV neutron radiation; minor radioactive waste clean-up costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

Most likely to be developed commercial fusion reaction involves the following:

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

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β^-, α] releases nuclear binding energy; early-stage technology; 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 possible fuels --- any element/isotope that can capture LENR neutrons; involves neutron-catalyzed transmutation of fuels into heavier stable elements; LENRs create → heat

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

Japan's beloved Mt. Fuji at dawn

Revolutionary ultralow energy neutron reactions (LENRs)

Radiation-free LENRs transmute stable elements to other stable elements

Fission and fusion

Evolution of nuclear technology

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

Totally explained by physics of Widom-Larsen theory

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

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

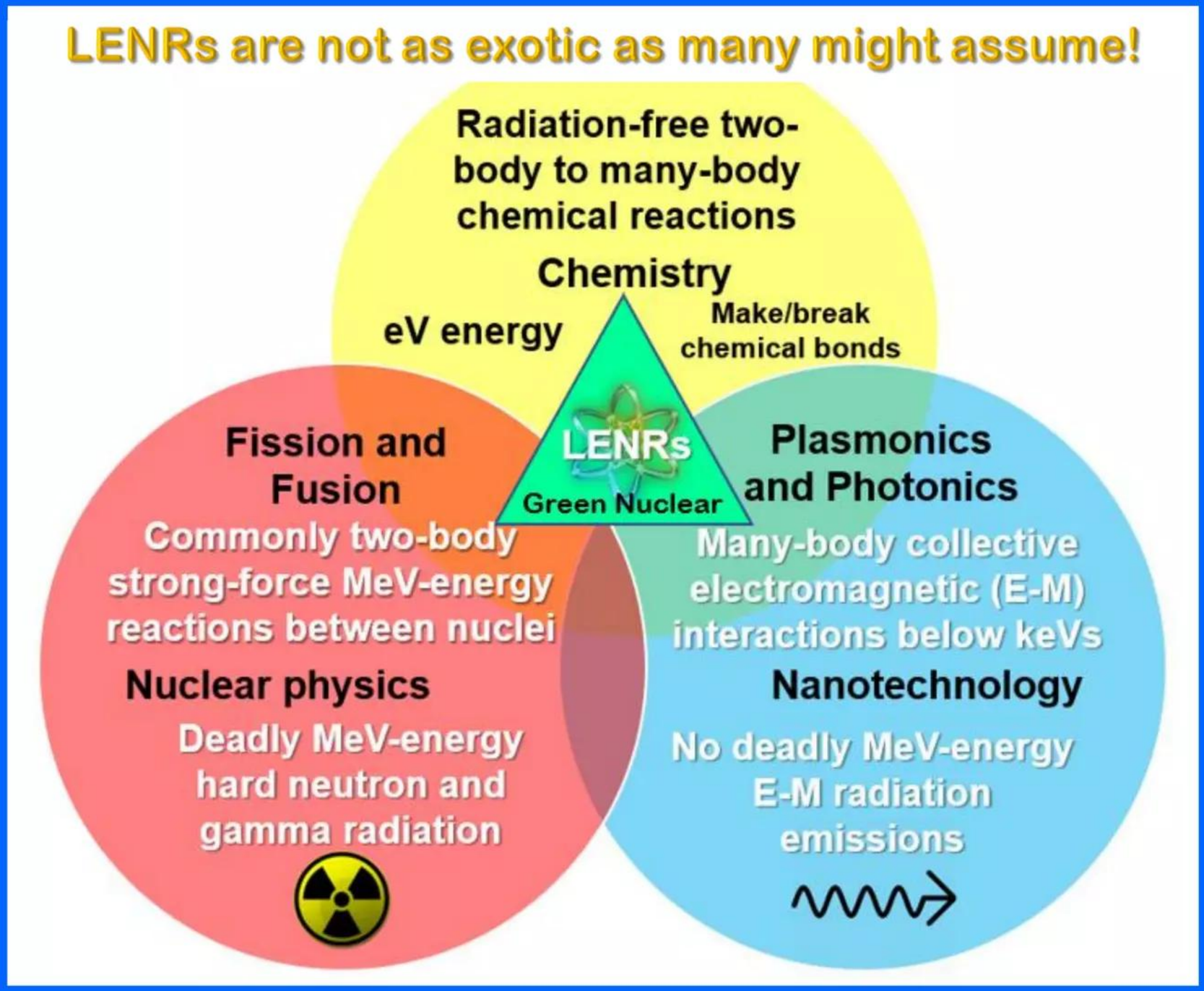
Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green CO_2-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations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

Visualization of plasmon electric field gradients on substrate surface

Surprisingly related: chemistry, nanotech & nuclear physics

Widom-Larsen theory relates chemistry and nanotech to LENR physics

Leverage theoretical & nanotech know-how to accelerate LENR development



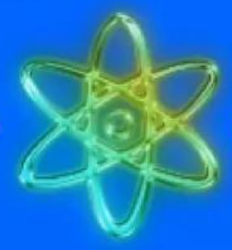
LENR technology could advance rapidly and surprise many

Nm-scale huge electric fields are common to chemical and $e + p$ catalysis

Few-body
Fission and fusion

Revolution in nuclear technology

Many-body collective Q-M processes



Safe green LENRs

LENR power generation technology could potentially advance very rapidly from this point and catch many by surprise. This is because Widom-Larsen theory, key applied nanotech, and materials science can be leveraged to greatly accelerate progress in future TRL stages (now at TRL-4). In that regard, Lattice recently discovered deep causal similarities between 'green' many-body collective electroweak nuclear catalysis (safe neutron-producing $e + p$ LENR reaction in condensed matter), enzymatic catalysis, and ordinary chemical catalysis; see public Lattice PowerPoint:

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

Electroweak neutron production in Widom-Larsen theory

Protons or deuterons can react directly with electrons to make neutrons

Input energy required to trigger many-body e_n+ p_n reactions in LENR active sites

Input energy boosts electric fields >10^{11} V/m

Collective many-body quantum effects: many *sp* electrons each transfer little bits of energy to a much smaller number of *sp* electrons also bathed in same nuclear-strength local electric field > 10^{11} V/m

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

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

Input energy

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

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 processes

Neutrons + atomic nuclei ⟶ heavier elements + decay products

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

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

Neutron capture-driven transmutation of isotopes and elements

Summary of steps in Widom-Larsen theory of LENRs

5-step process in active sites occurs in 200 - 400 nanoseconds or less

Microscopic many-body surface 'islands' of protons become LENR active sites

1. Collectively oscillating, quantum mechanically entangled, many-body 'islands' of Hydrogen (either +-charged protons or deuterons) will form spontaneously on metallic hydride surfaces or at certain types of interfaces, e.g. metal/oxide

2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and protons in 'islands'; injection of input energy creates nuclear-strength local electric fields > 6.88 x 10^{11} V/m - increases effective masses of surface plasmon electrons in islands

3. Heavy-mass surface plasmon electrons formed in many-body 'islands' then react directly with electromagnetically interacting protons; process creates neutrons and neutrinos via many-body collective electroweak $e + p$ reaction

4. Neutrons collectively created in patch have ultralow kinetic energies and are all absorbed locally by nearby atoms - no dangerous energetic neutron emissions escape apparatus; any locally produced or incident gammas are converted directly into safe infrared photons (heat) by unreacted heavy electrons (Lattice issued patent US# 7,893,414 B2) - no hard MeV-energy gamma emissions

5. Heat-producing nuclear transmutation of elements begins in LENR active sites; only survive for 200 - 400 nanoseconds before being destroyed by intense heat

Widom-Larsen theory provides model for LENR active sites

LENR active site precursors can be rationally designed and fabricated

Active sites intrinsically microscopic: size ranges from 2 nm up to 100 - 200 μ

- Widom-Larsen theory posits that LENRs occur in localized micron-scale LENR active sites; located on ~planar substrate surfaces, at certain types of interfaces, or on curved outer surfaces of fabricated nanoparticles
- LENR active sites survive for under ~ 200 - 400 nanoseconds before being destroyed by heating; local peak temperatures can reach 4,000 - 6,000^{o} C
- LENR active sites will *spontaneously* form and reform on device surfaces under proper operating conditions in well-engineered LENR materials
- Simultaneous triggering of ~100 LENR active sites 100-μ in diameter on Ni can release 1^{+} Watt of excess heat in < 1 second. May form very distinctive crater-like structures on substrate surfaces (visible in SEM images); some crater morphologies indicate high temperature flash-boiling of metals (Pd)
- Peak local LENR power density in microscopic LENR active sites can briefly exceed 1.0 x 10^{21} Joules/sec·m^{3} during their very short lifetimes
- Control and maintain macroscopic-scale temperatures inside LENR reactors by tightly regulating total input energy and/or total area/volumetric densities of LENR active sites inside reaction chambers

Input energy creates high electric fields in LENR active sites

Born-Oppenheimer breakdown enables nuclear-strength local E-fields

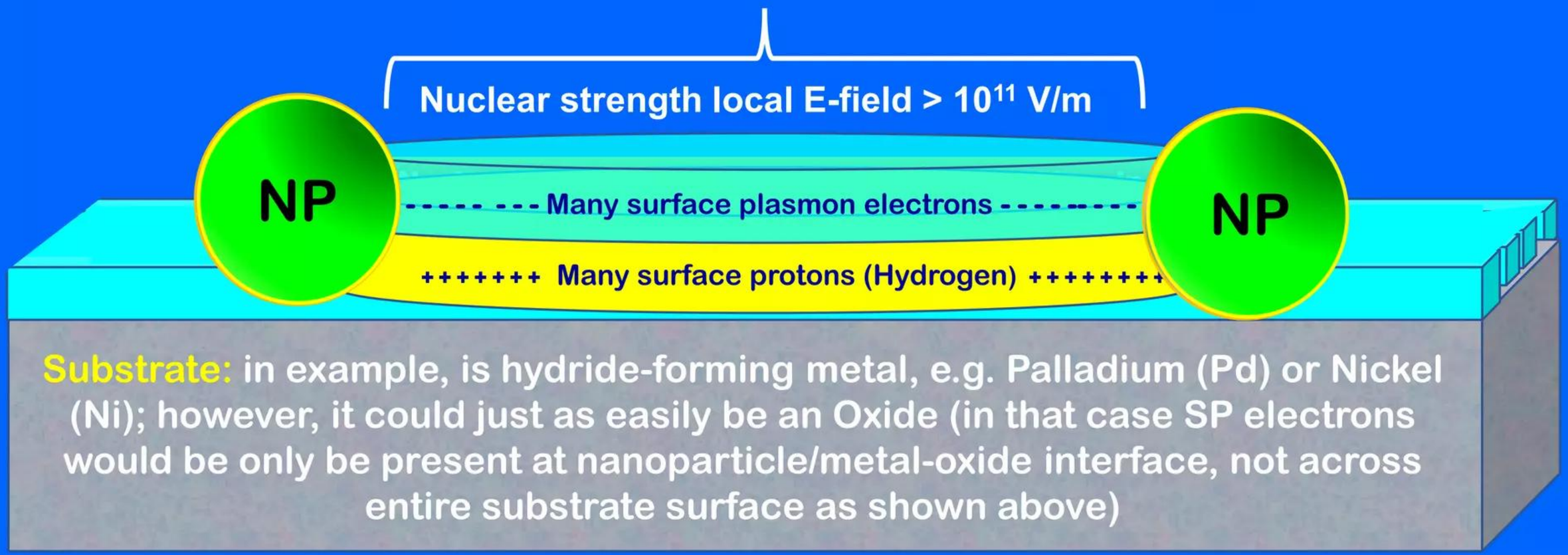
Huge electric field increases effective masses of SP electrons in active sites

Many-body collective electroweak reaction produces neutrons and neutrinos

Input energy$_{\text{E-field}}$ + $e^-_{plasmon} \rightarrow e_n^{-*} + p_n^{+} \rightarrow n + \nu_e$ **[condensed matter surfaces]**

Input energy creates enormous local E-fields > 10^{11} V/m between adjacent nanoparticles

Single nascent LENR-active site is many-body 'island' of Q-M entangled protons and electrons



NP = metallic nanoparticles resting on substrate surface

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, used to design LENR active site precursors

Figure 1.

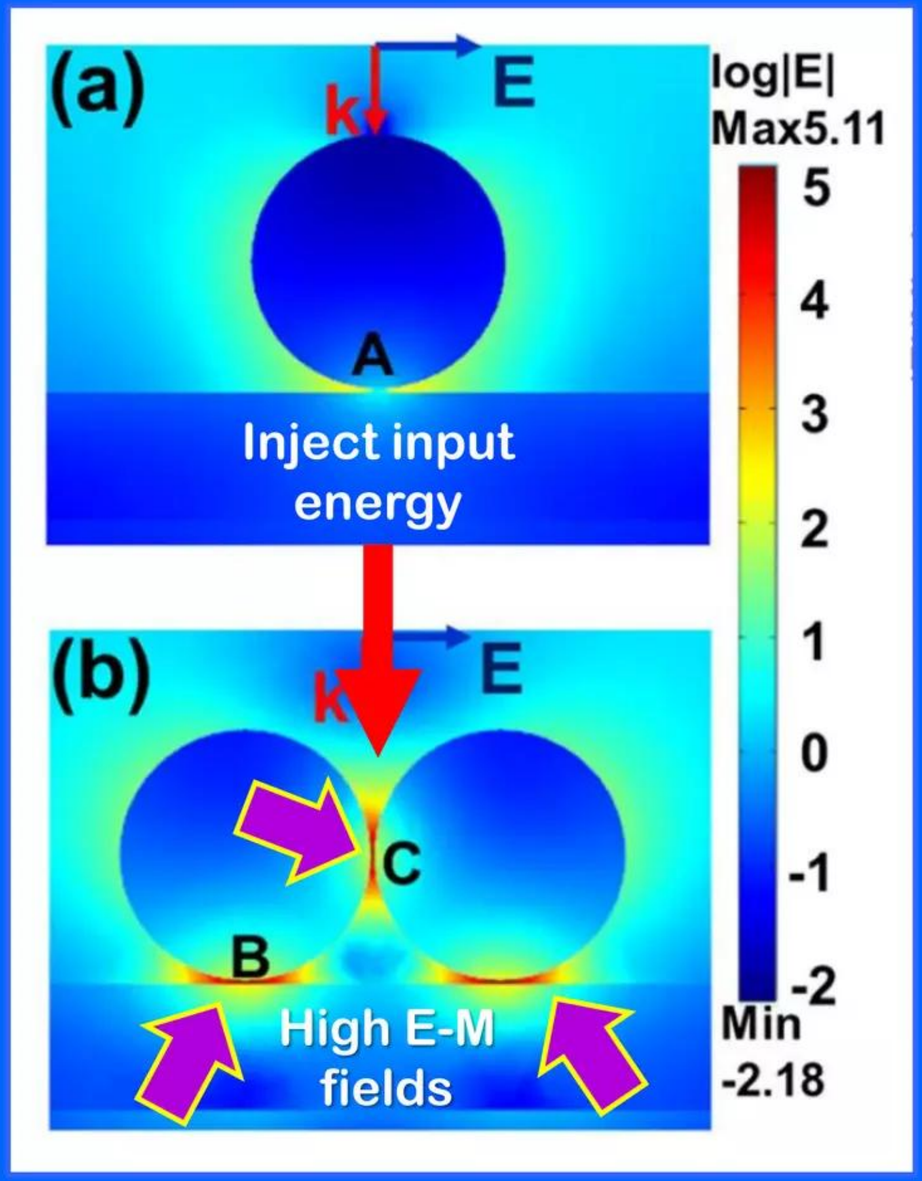
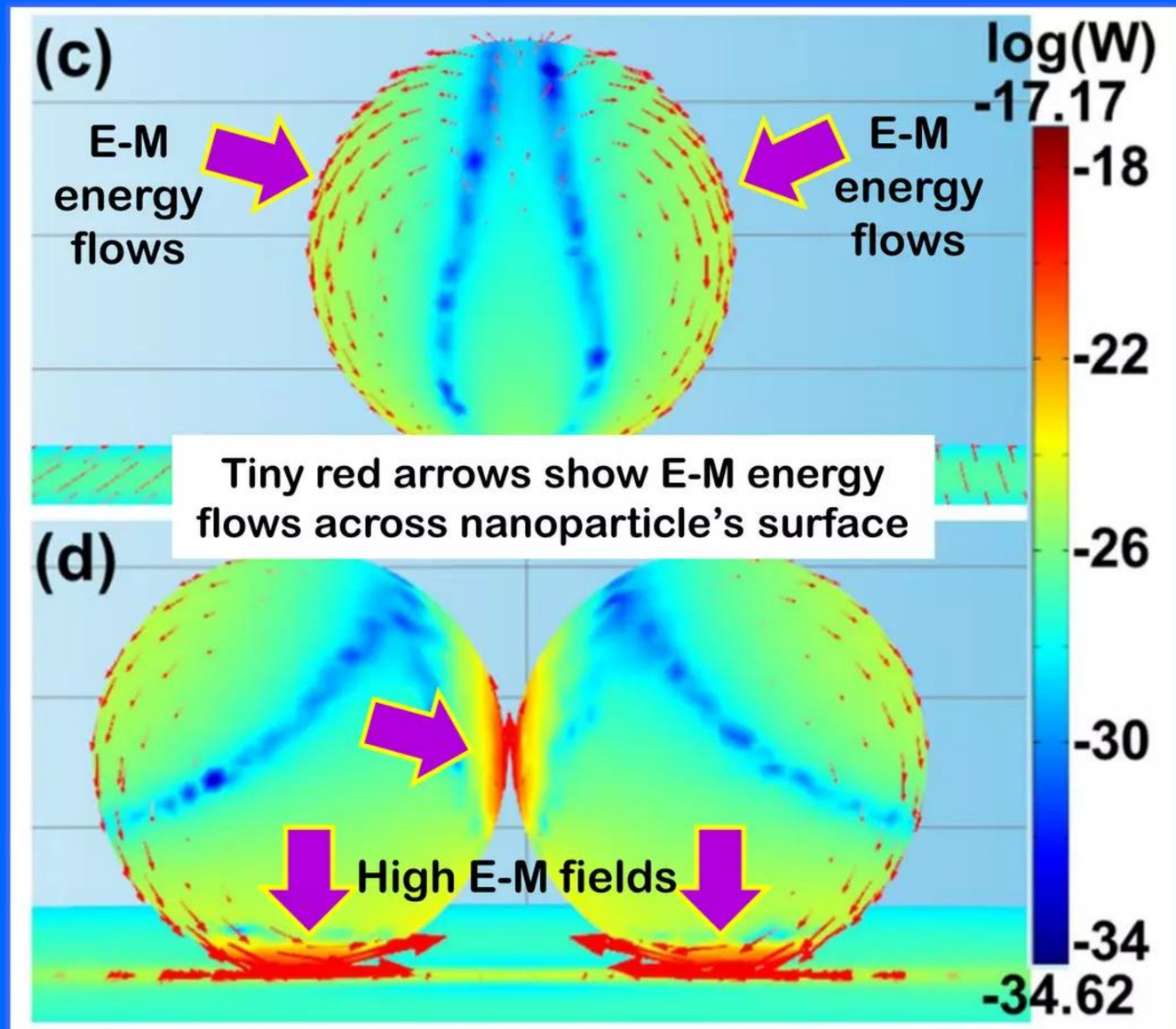


Figure 3.



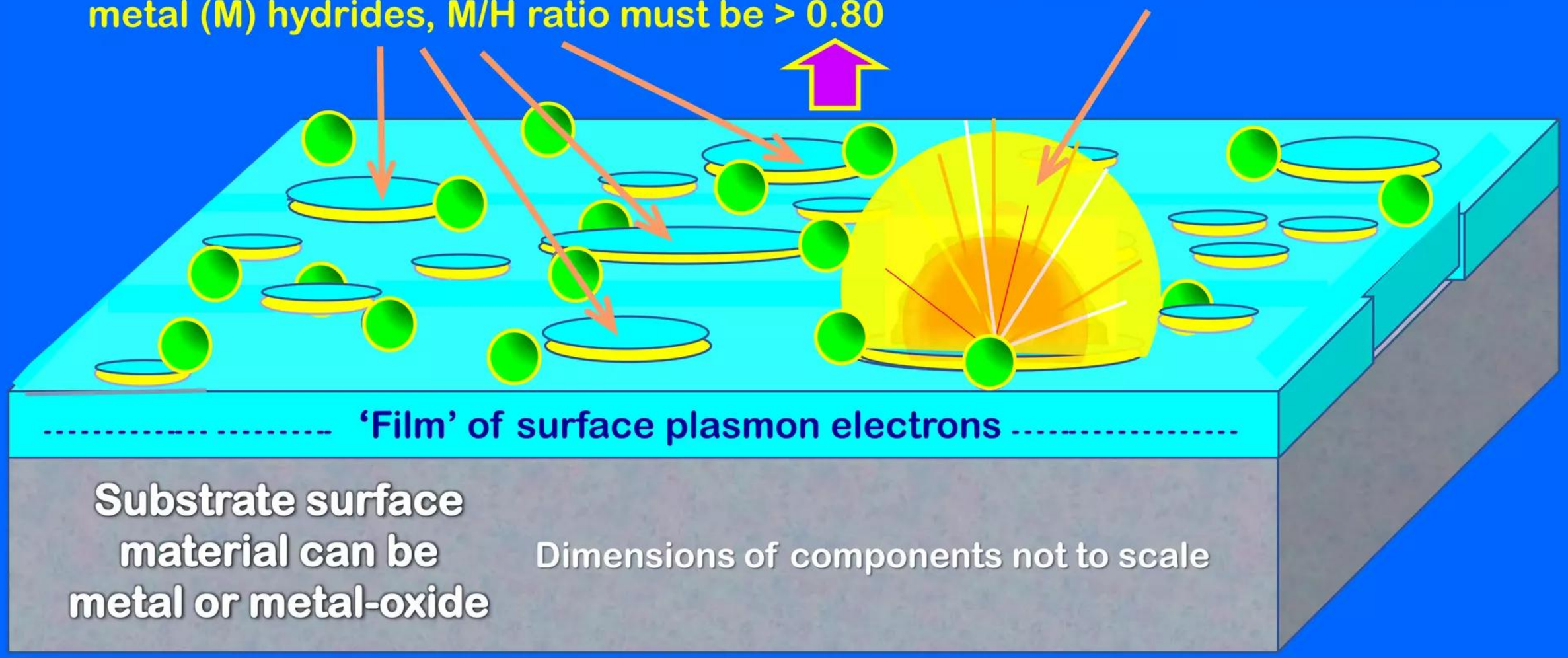
http://publications.lib.chalmers.se/records/fulltext/178593/local_178593.pdf

Many-body ‘islands’ of protons & electrons form active sites

Islands are precursor nanostructures that can become LENR active sites

Many-body ‘islands’ of quantum entangled, collectively oscillating protons (yellow) and surface plasmon electrons (blue) can form spontaneously on substrate surfaces; for metal (M) hydrides, M/H ratio must be > 0.80

Intense heating in LENR active sites can form μ-scale ‘craters’ on substrates or NP surfaces



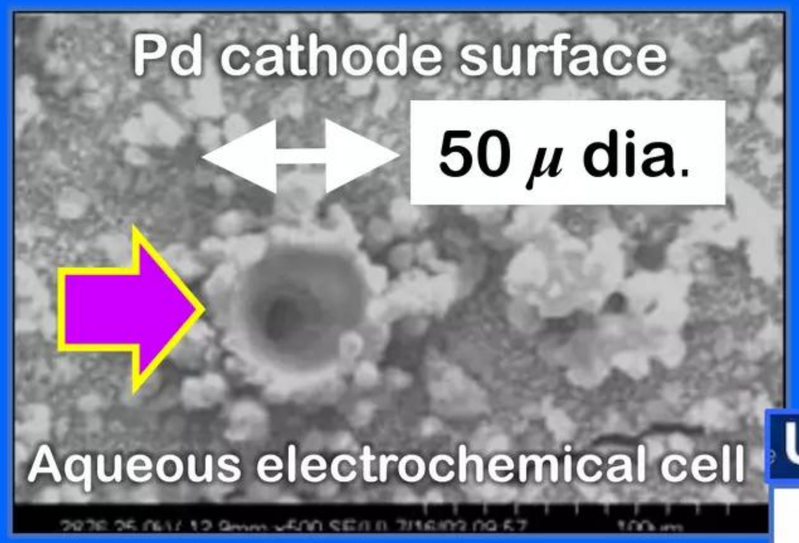
= metallic nanoparticles resting on substrate surface

LENR active sites create distinctive surface nanostructures

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

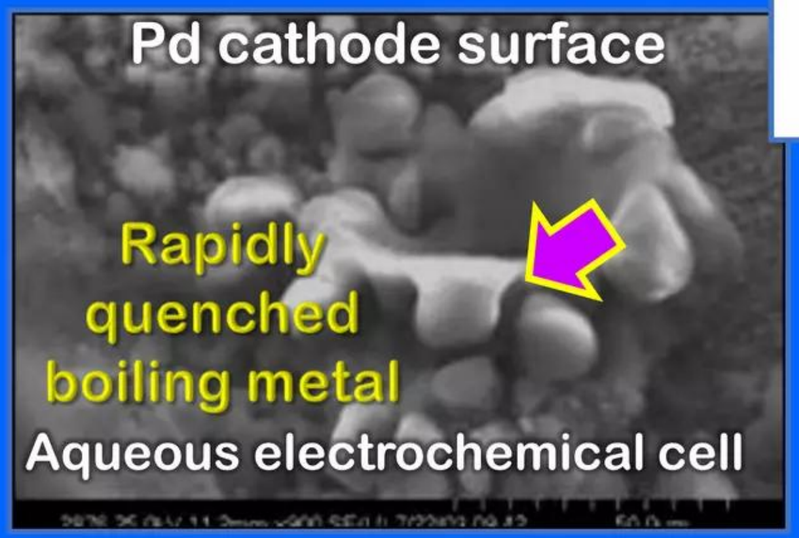
Post-experiment SEM images of Pd surface; infrared video of working Pd cathode

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

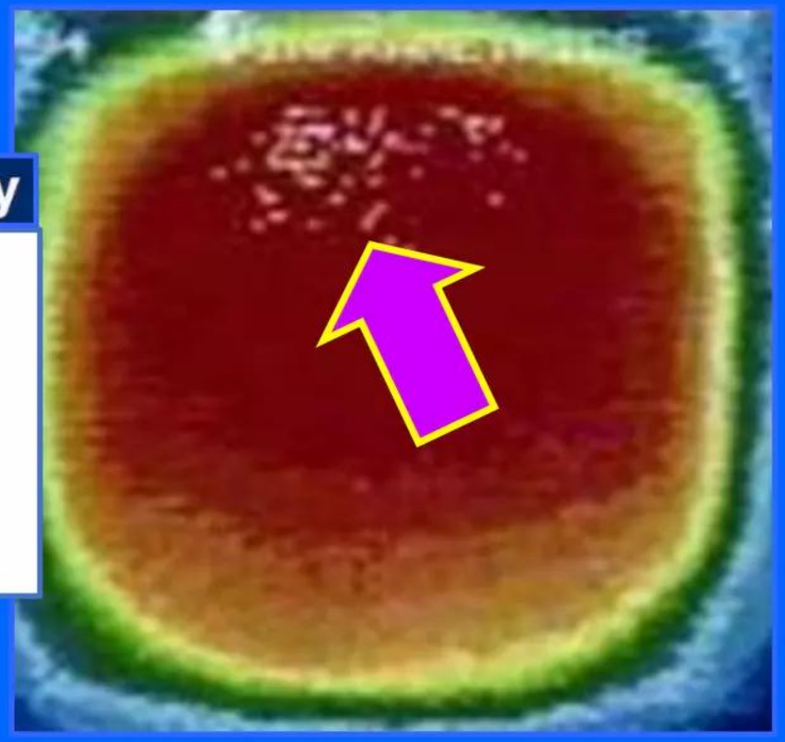
United States Navy

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, U.S. Navy SPAWAR (1994)

Boiling point of Palladium = 2,963°C

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

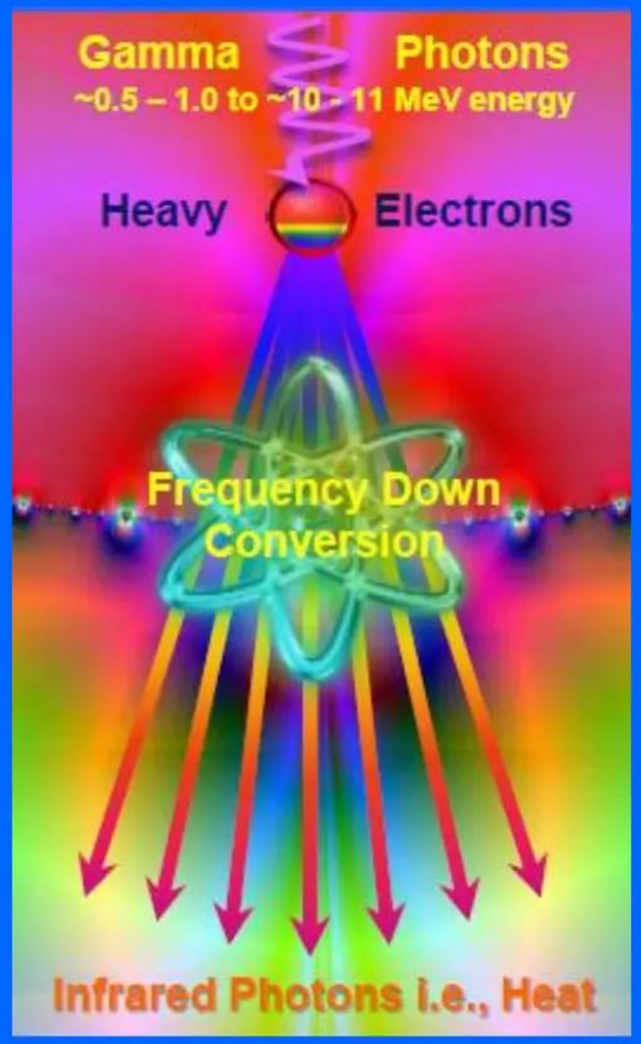
Key LENR process covered by Lattice's issued U.S. patent #7,893,414 B2

"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 are green: no energetic radiation or radwastes

Lack of hard radiation obviates need for shielding and containment

Major opportunity to develop broad range of competitive LENR power sources

Fission and fusion processes both emit deadly MeV-energy neutron and gamma radiation

Fission reactors need 1 foot of steel and 3 feet of concrete to protect human beings from dangerous hard radiation and wastes emitted by reactor; systems intrinsically large and heavy

Revolution in green nuclear technology

LENRs could enable future development of small, portable battery-like power sources that are very safe and disposable

Much larger LENR systems based on dusty plasma embodiments could potentially scale-up to megawatts

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

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

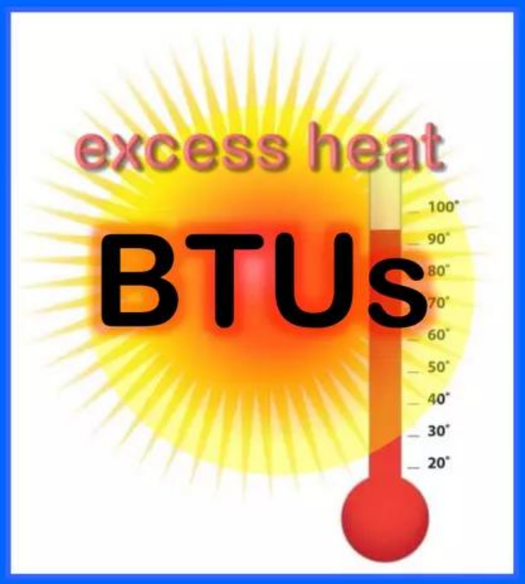
Catalytic neutron 'match'

Neutrons are readily absorbed 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

capture +

produces →



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

Safe ultra low energy neutrons release heat from LENR fuels

Neutron capture by target fuel nuclei triggers releases of stored energy

- **Ultra low energy LENR neutrons function like catalytic 'matches' that 'light the logs' of target fuel nuclei.** Neutron-catalyzed LENR transmutation networks release nuclear binding energy that was stored and locked away in nuclei 'fuel logs' when they were originally produced many billions of years ago at tens of millions of degrees in fiery nuclear processes inside cores of long-dead stars
- **Excess heat produced by LENR transmutation networks comes mainly from direct conversion of gamma photons (γ) into infrared photons (IR) by heavy electrons present in LENR active sites;** gammas arise from neutron captures on fuel targets as well as from β and other type of decays. IR is then absorbed by local matter, heating it up – **Lattice has fundamental U.S. patent on this process**
- **Lesser amounts of heat comes from nuclear decays of unstable neutron-rich isotopes that emit energetic particles** (e.g., betas, alphas, protons, etc.); these particles transfer their kinetic energy by impacting on local matter, which is then heated – **such decays do not emit deadly hard radiation requiring shielding**
- **Neutrino particles from weak interactions do not contribute to any production of usable heat;** they essentially bleed-off a small portion of released nuclear binding energy outward into space; unavoidable neutrino emissions are part of energetic cost of energy releases in LENR transmutations via green β^- decays

Periodic Table of chemical elements found in the Universe

LENR transmutation of target fuels proceeds from left-to-right along rows

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

Specific energy of LENR Ni target fuel > 3 million x chemical

Fission reactions emit deadly radiation – LENRs are hard-radiation-free

Fuel	Energy Type	Specific energy (MJ/kg)	Direct uses
Uranium (in breeder)	Nuclear fission	80,620,000	Electric power plants (nuclear reactors)
Thorium (in breeder)	Nuclear fission	79,420,000	Electric power plants (Nuclear reactors)
Electrons, protons (Hydrogen), and LENR target fuels	**Nuclear but neither fission nor fusion**	**Nickel target fuel ~ 3,817,235 Ni**	**Electric power plants; stationary, mobile, and portable power & propulsion applications**
Hydrogen (compressed at 70 MPa)	Chemical	142	Rocket & automotive engines, grid storage& conversion
Diesel/Fuel oil	Chemical	48	Automotive engines, power plants
LPG (including Propane/Butane)	Chemical	46.4	Cooking, home heating, auto engines, lighter fluid
Jet Fuel	Chemical	46	Aircraft
Gasoline (Petrol)	Chemical	44.4	Automotive engines, power plants
Ethanol (E100)	Chemical	26.4	Flex-fuel, racing, stoves, lighting
Coal	Chemical	24	Electric power plants home heating
Methanol fuel (M100)	Chemical	19.7	Racing, model engines, safety
Wood	Chemical	16.2	Heating, outdoor cooking

These fuels represent chemical energy sources

Enormously lower values for specific energy

Nanoparticulate LENR fuels could be used in many systems

Possible LENR target fuels include Nickel, Lithium, and aromatic Carbon

Commercial LENR fuels energy densities would be > 5,000x larger vs. gasoline

- **Revolutionary performance:** automobile, truck, aircraft, or ship powered by LENRs could travel around entire world on quantity of nanoparticulate fuel that would fit into a large FedEx box. LENR fuels would be inert and benign and could utilize existing overnight package delivery systems 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 would fit into 1 - 2 FedEx boxes

Japanese government now targeting LENR commercialization

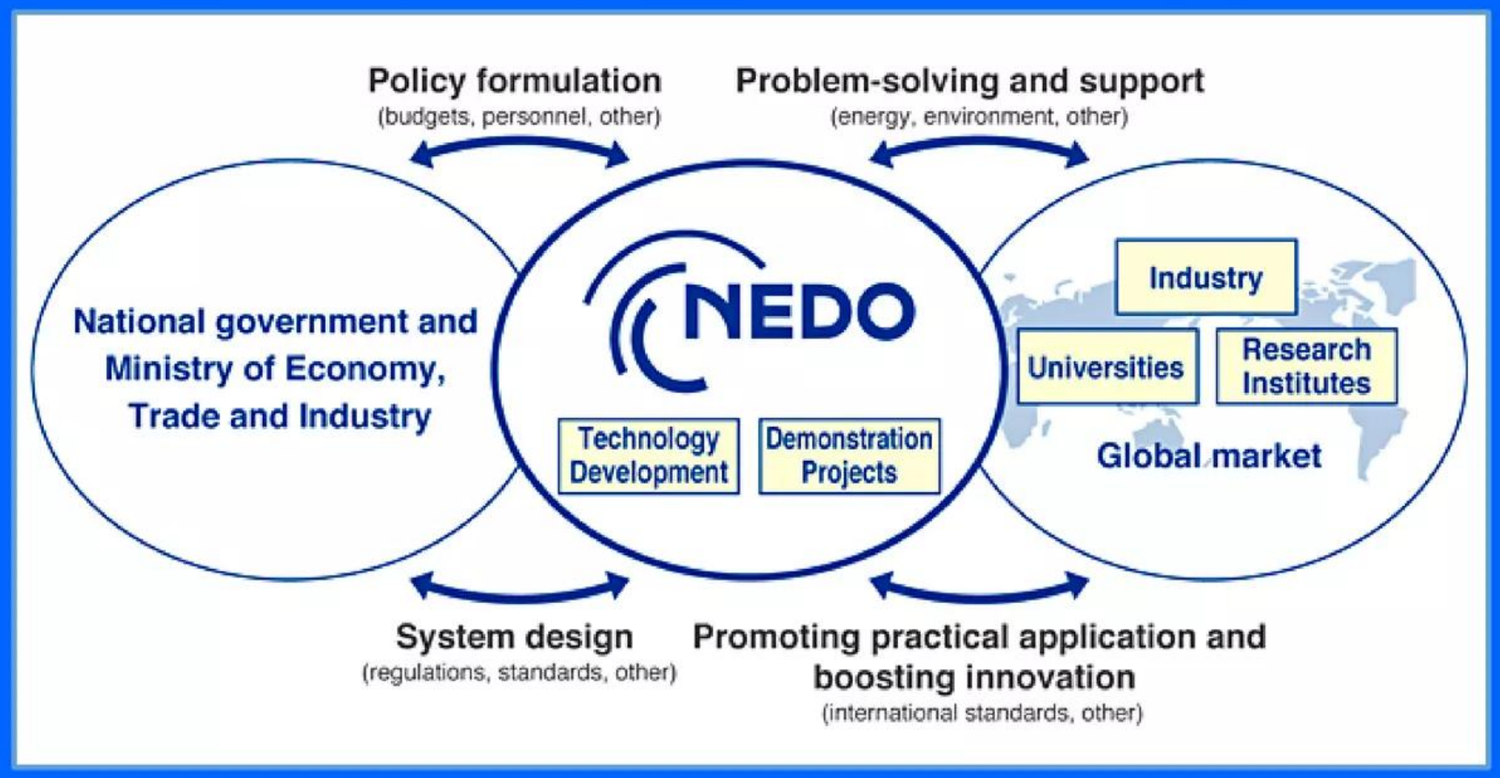
2015: NEDO organized and funded LENR project with industry & academia

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 further enhancing Japan's industrial competitiveness

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

NEDO's mode of operation – graphic copied from home page of NEDO website



経済産業省 Ministry of Economy, Trade and Industry

MITSUBISHI

TOYOTA

NISSAN

Mitsubishi began using D_2 gas permeation method in 2001

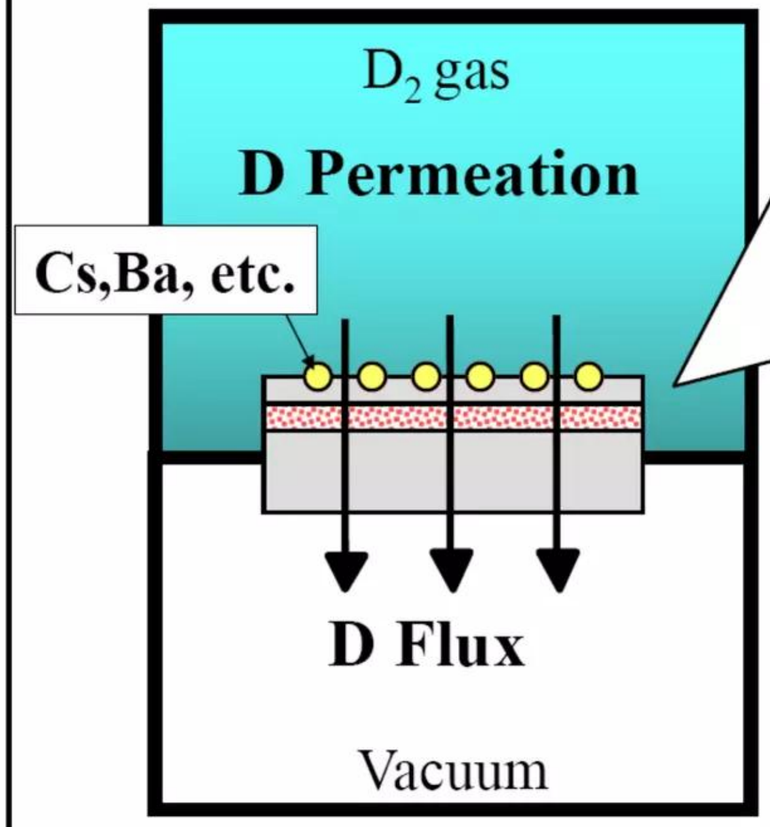
Many successful transmutation results; primarily reported at conferences

90⁺ % success rate for demonstrating nanoscopic quantities of transmutation products

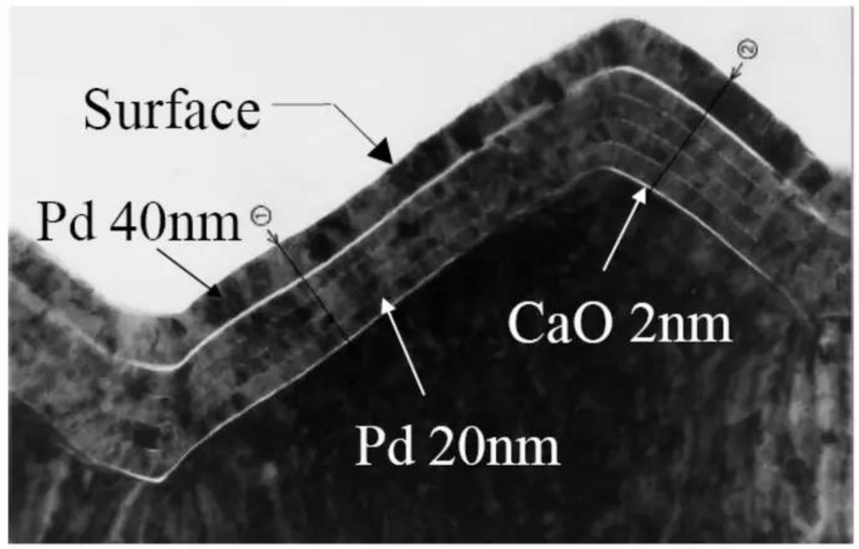
Features of the Mitsubishi Method

MITSUBISHI HEAVY INDUSTRIES
TECHNOLOGY & INNOVATION HEADQUARTERS

D_2 gas permeation through nano-structured Pd complex



Pd nano-sized multilayer film



3

MHI slide from ICCF-18 (2013)

https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

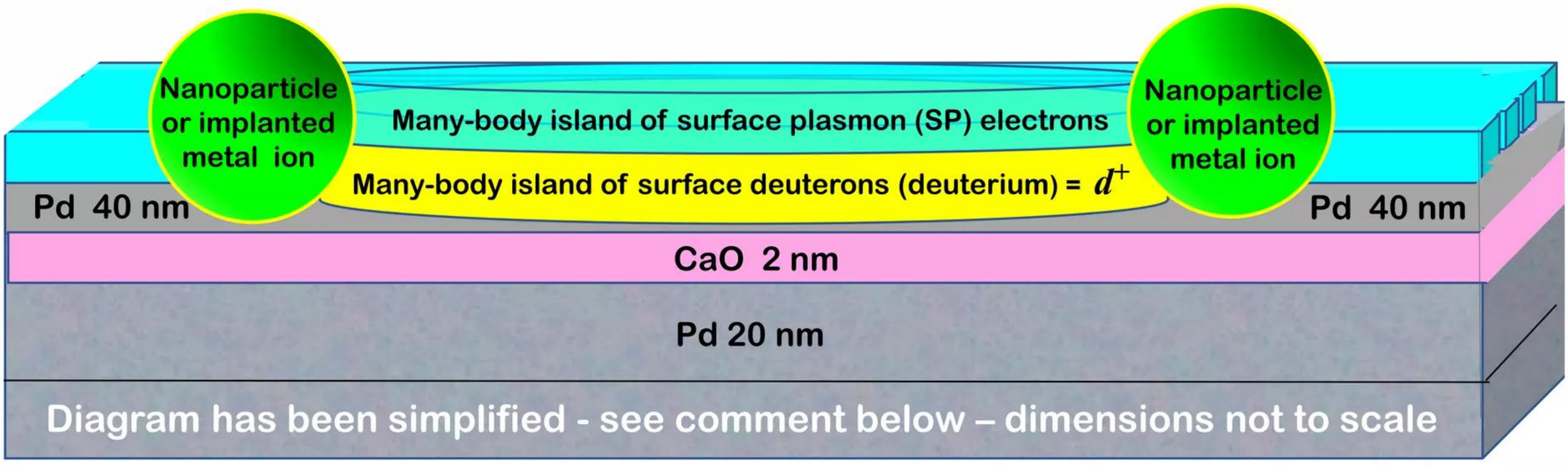
Widom-Larsen theory on Mitsubishi gas permeation method

Input energy is provided by D_2 pressure gradient and moderate heating

$$\text{Input Energy}_{\text{E-field}} + e_{\text{n}}^{-}{}_{sp} \rightarrow e_{\text{n}}^{-*}{}_{sp} + d_{\text{n}}^{+} \rightarrow 2\, n^{0}{}_{\text{ule}} + \nu_e$$

Electroweak reaction between deuterons and SP electrons produces ultralow energy neutrons

LENR active sites can form on or near ~ planar substrate surfaces, near or on curved surfaces of nanoparticles, and/or near implanted ions



SP electrons, nanoparticles, implanted ions, and thin film heterostructure component dimensions are not to scale; surface layer is of Pd (thickness = 40 nm); MHI's entire structure is not shown --- repeated structural units consists of 5 layers of CaO (thickness = 2 nm) interleaved with 4 layers of Pd (thickness = 20 nm); lowermost layer of Pd that is in direct contact with vacuum (thickness = 0.1 mm)

Mitsubishi successfully demonstrated LENR transmutations

Many successful transmutation results; Toyota confirmed Cs → Pr (2013)

Transmutation of Tungsten→Osmium→Platinum: American Nuclear Society Meeting (2012)

Reactions observed so far in MHI

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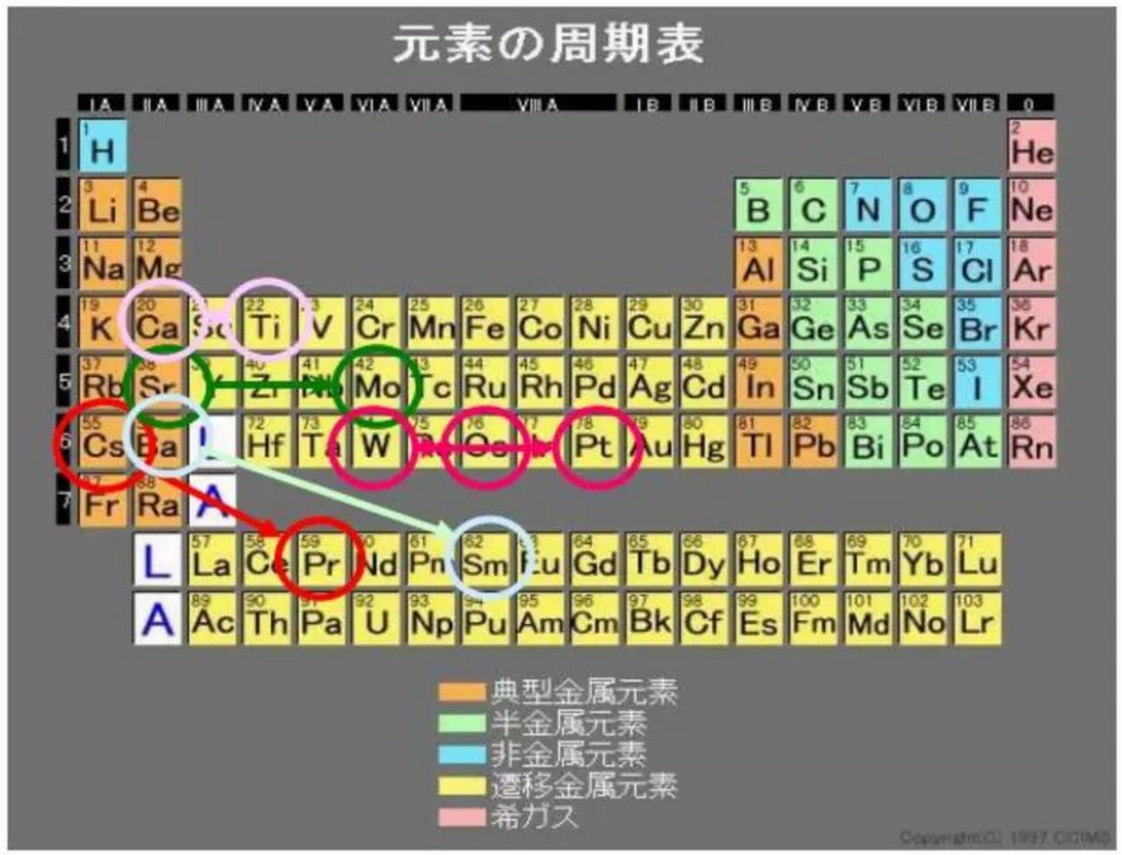


$$^{133}_{55}Cs \xrightarrow{4d(2\alpha)} {}^{141}_{59}Pr$$

$$^{88}_{38}Sr \xrightarrow{4d(2\alpha)} {}^{96}_{42}Mo$$

$$^{138}_{56}Ba \xrightarrow{6d(3\alpha)} {}^{150}_{62}Sm$$

$$^{137}_{56}Ba \xrightarrow{6d(3\alpha)} {}^{149}_{62}Sm$$

$$^{44}_{20}Ca \xrightarrow{2d(\alpha)} {}^{48}_{22}Ti$$

$$^{184}_{74}W \xrightarrow{2d(\alpha)} {}^{188}_{76}Os$$

$$^{182}_{74}W \xrightarrow{4d(2\alpha)} {}^{190}_{78}Pt$$

1)Alkali metals; Electron Emitter
2)2d, 4d, 6d; α capture reactions

5

MHI slide from ICCF-18 (2013)

https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

MHI transmuted implanted Tungsten to Osmium and Platinum

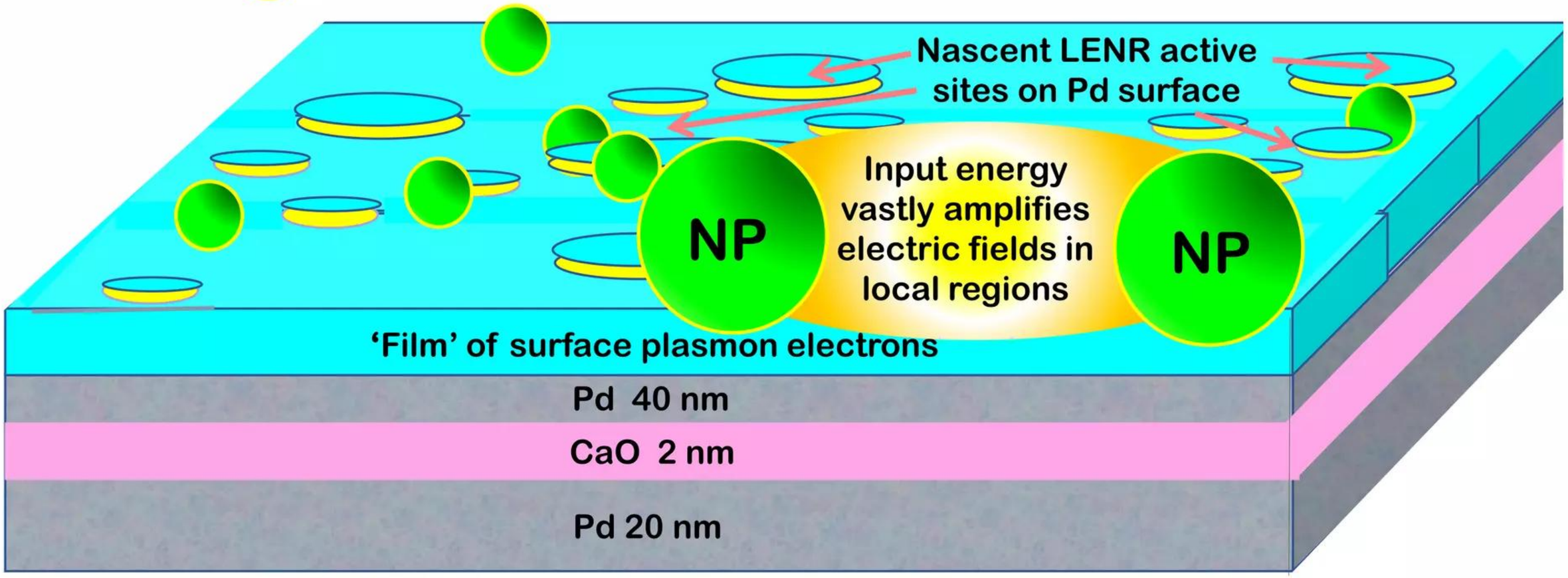
Multi-step neutron-catalyzed LENR pathway begins with Tungsten target

Mitsubishi D_2 gas permeation method: Tungsten (W) → Osmium (Os) → Platinum (Pt)

$n^0 + (Z, A) \rightarrow (Z, A+1)$ ULE neutrons were captured by implanted W target atoms

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_\beta^- + \nu_e$ beta$^-$ decay transmutes Pd to Os then Pt

NP = multiatom nanoparticle (NP) or implanted W^+ (Tungsten) ions



LENR device heterostructure has been simplified – dimensions not to scale

NEDO's recent LENR results: key technological advancement

LENR devices created Watts of excess heat with 70 - 80% reproducibility

- NEDO LENR project's Pd/Ni/Zr devices' excess heat performance exceeded 99% of all results produced by LENR Pd/Pt electrochemical cells that probably comprised 70 - 80% of experimental systems utilized in LENR field since 1989
- Excess heat performance of NEDO project LENR devices also vastly exceeded planar thin-film multilayer Pd/CaO metal-oxide heterostructures through which H_2 or D_2 gas was permeated with modest pressure gradients; Mitsubishi Heavy Industries (MHI) developed this experimental method in 2001. Was excellent for demonstration of LENR transmutation products found in microscopic surface domains with SIMS or XPS analysis; input energy with MHI permeation method too low to make enough ULE neutrons to create readily measurable excess heat
- NEDO project's nanocomposite LENR devices achieved best-ever performance in history of field since 1989 with respect to average peak Watts of measured excess heat production and % of experiments that successfully created heat
- Technology readiness-wise, NEDO LENR project's recent technical progress with excess heat production and reproducibility is a watershed development. Technology readiness level of LENRs is arguably now early TRL-4 (European Commission definitions); completion of stage TRL-9 represents successful introduction of commercial consumer products. Achieving TRL-4 is important milestone in development of LENRs into useful commercial energy technology

Project leveraged nanotech, materials science & cleanrooms

Designed/fabricated multi-metal alloys for nanocomposite LENR devices

- NEDO project nanocomposite LENR test devices are various alloys of Ni, Pd, Cu, and Zr along with ZrO_2 or SiO_2 metal-oxide filler particles. Fabricated in semicon-like cleanrooms; leveraged relevant nanotech and materials science knowledge
- LENR devices are purpose-built, ~ spherical nanoparticles with dimensions in nm. Composed of 'designed' alloys with varied molar ratios of Ni, Pd, Cu, Zr; Ni, Pd, Zr form hydrides that are gas-loaded with Hydrogen or Deuterium to M/H(D) ratio >.80
- LENR device types include: PS (Pd-SiO_2), CNS (Cu-Ni-SiO_2), PNZ (Pd-Ni-Zr), or CNZ (Cu-Ni-Zr); are intermixed with either ~1 mm SiO_2 or ZrO_2 filler substrate beads
- NEDO project LENR test devices were carefully 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, among others

Atomic composition for Pd_1Ni_{10}/ZrO_2 (PNZ6, PNZ6r) and Pd_1Ni_7/ZrO_2 (PNZ7k)

Technova Inc.

24 Watts

Sample	Mass (g)	Molar ratio				ZrO_2 filler mass (g)
		Ni	Pd	Zr	O	
PNZ6	124.2	**0.318**	**0.032**	**0.650**	0.240	1377
calcined at 450°C·60h		10 : 1				
PNZ6r	131.9	**0.318**	**0.032**	**0.650**	1.03	1378
recalcined at 450°C·60h		10 : 1				
PNZ7k	99.8	**0.306**	**0.044**	**0.650**	0.274	1531
calcined at 450°C·60h		7 : 1				

24 Watts

Technova Inc.

Energetics for LENR transmutation of Nickel (Ni) target fuels

NEDO: PNZ samples with highest molar ratio of Ni created greatest heat

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

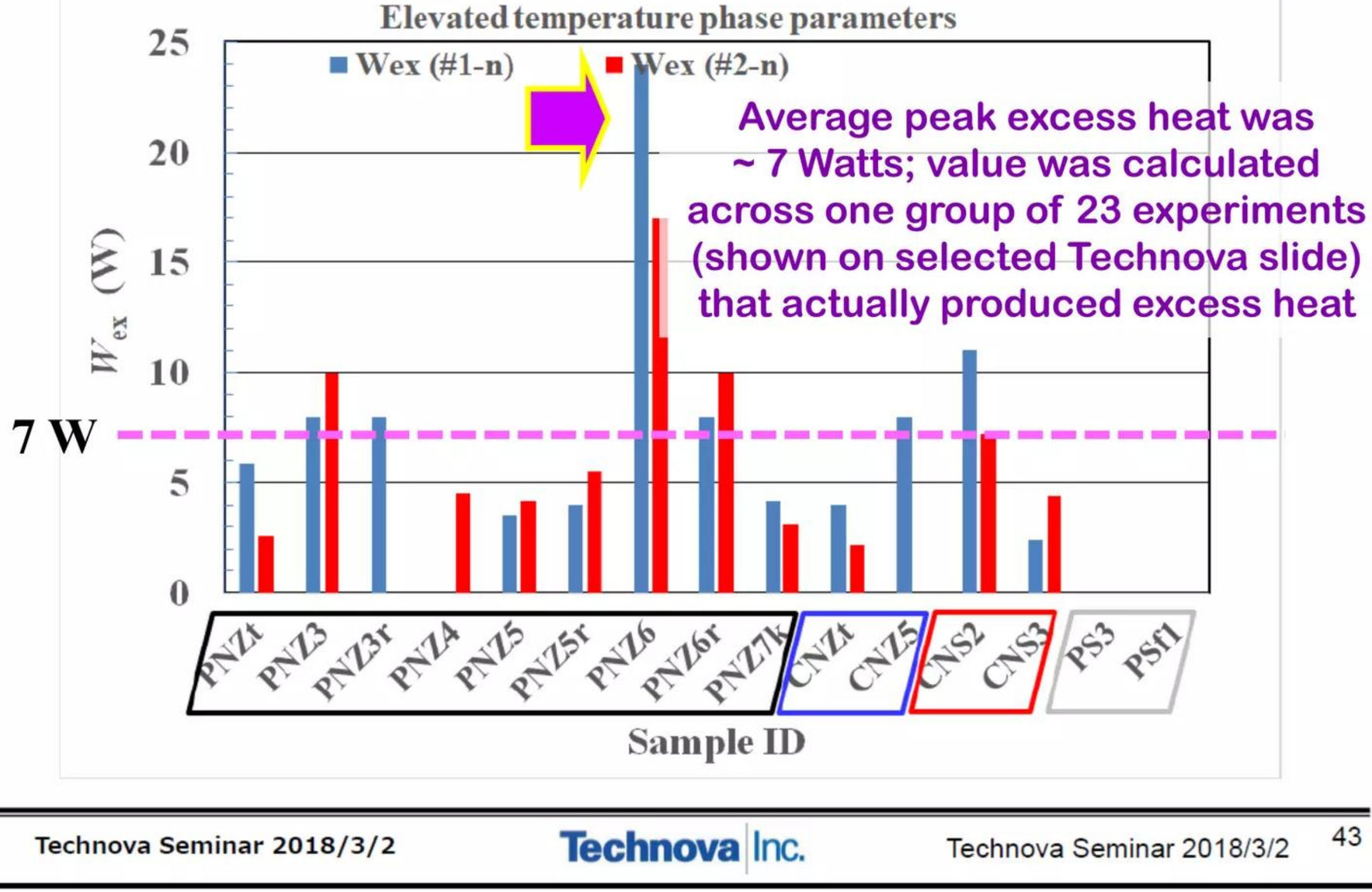
Isotope Capturing ULM Neutron or Beta decaying	Natural abundance of stable isotope	Neutron capture Q-value in ~MeV (all are + values)	Contribution to weighted average based on natural abundance	Comments and calculations Assume Hydrogen used for proton (p^+) source
Ni-58	68.0%	9.0	6.94	Assume ULE neutron 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

NEDO LENR project experiments report Watts of excess heat

~77% of this experimental series produced avg. ~ 7 Watts of excess heat

PNZ6: peak instantaneous power of 24 Watts was produced by 120 grams of nanoparticles

Largest excess power was observed by PNZ6 (Pd_1Ni_{10}/ZrO_2) 120g



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

NEDO LENR project results decisively refute taunt of skeptics

Asserted LENR devices "cannot boil enough water to make a cup of tea"

- 120 grams of nanoparticulate (PNZ6 Pd_1Ni_{10}/ZrO_2) continuously produced at least 10 Watts of excess heat for more than one month. This performance equates to cumulative excess heat of at least ~7.2 kWh or 25.9 MJ; that much heat is more than enough thermal energy to readily boil over 300 cups of water to make tea
- Several NEDO project experiments achieved instantaneous peak excess heat production of ~ 24 - 25 Watts. As to cumulative total quantity of excess heat created over entire duration of single experiments, several produced 80 - 90 Megajoules per mole (MJ/mol.) of absorbed Hydrogen or Deuterium. Cannot be chemical process because complete combustion of H_2/D_2 is only 0.286 MJ/mol.
- Recently reported experimental results of Japanese NEDO project unequivocally showed that a critical technological hurdle in commercializing LENRs for power generation has been surmounted. Use of modern semiconductor cleanroom and nanotech fabrication methods enabled creation of nanocomposite, binary-metal LENR device materials able to reproducibly create multiple Watts of excess heat

~0.0826 MJ of thermal energy is required to boil enough water to make a single cup of tea. 24 - 25 Watt thermal source will heat that much water from room temp up to 100° C boiling point in about 1 hour

NEDO results 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.

"Ugly" prototype of nuclear fission reactor first built in 1942

CP-1 reactor weighed 400 tons and produced ~ 0.5 Watts of excess heat

10^7 x output increase

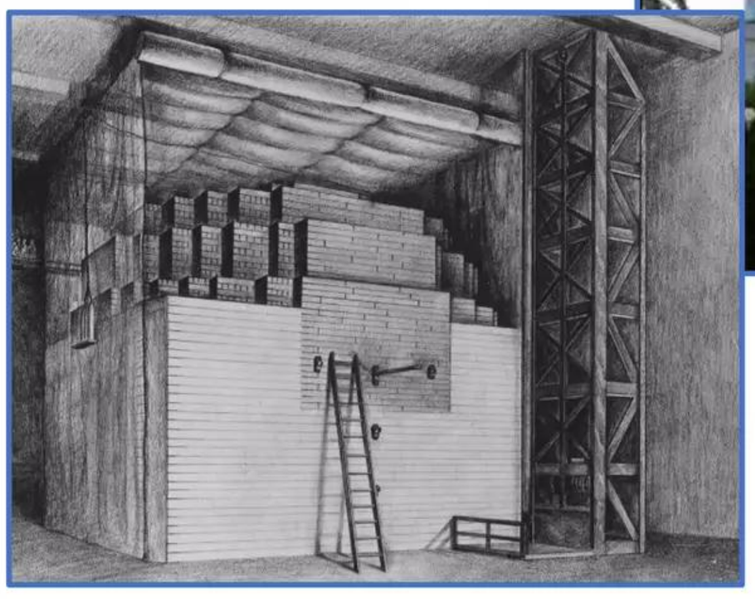
12 years

Further 10^3 x increase

Total increase 10^{10} x vs. 1942

World's 1st sustained fission chain reaction

5×10^{-1} Watts



1942: Manhattan Project
CP-1 USA 0.5 W

5×10^6 Watts

1954: Obinsk, Russia
5 MW
World's 1st commercial grid-connected fission power plant

8.2×10^9 Watts

2018: Kashiwazaki-Kariwa
Japan 8.2 GW
World's largest multi-reactor fission power plant

Power output of fission reactors has increased by ~10^{10} x over 76 years

"Ugly" prototype of 1st semiconductor transistor built in 1947

1947 prototype fit on palm of hand --- transistors today are ~ 10^6 x smaller

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 = ~ 1.3×10^7 nm

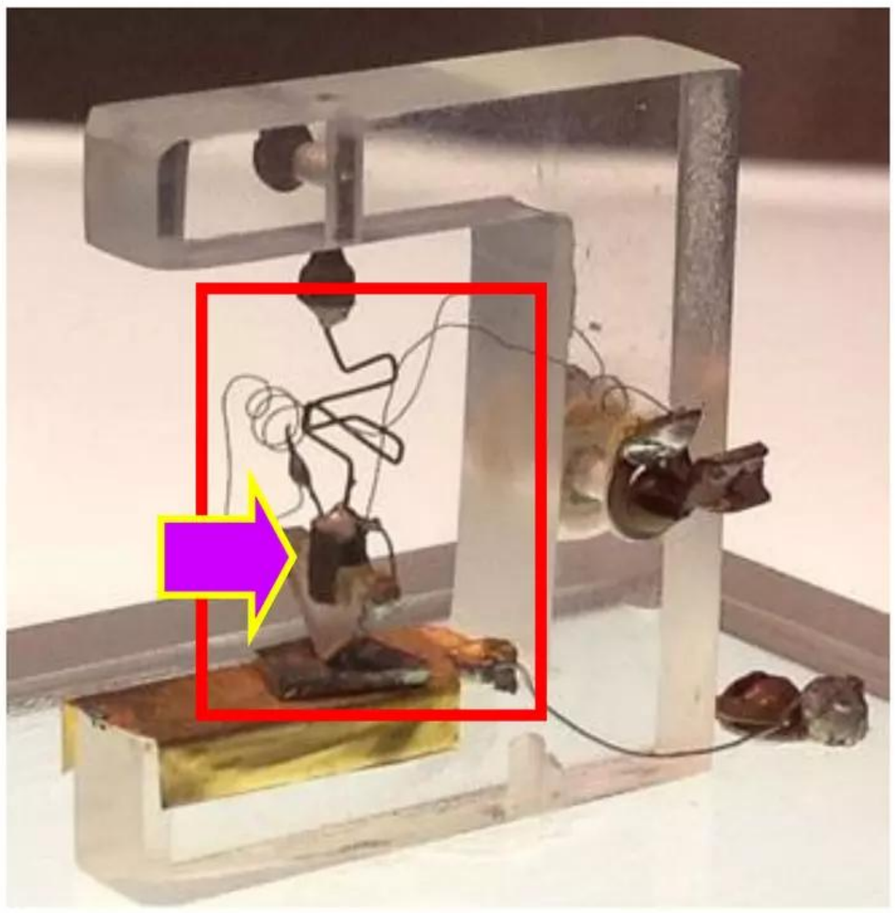


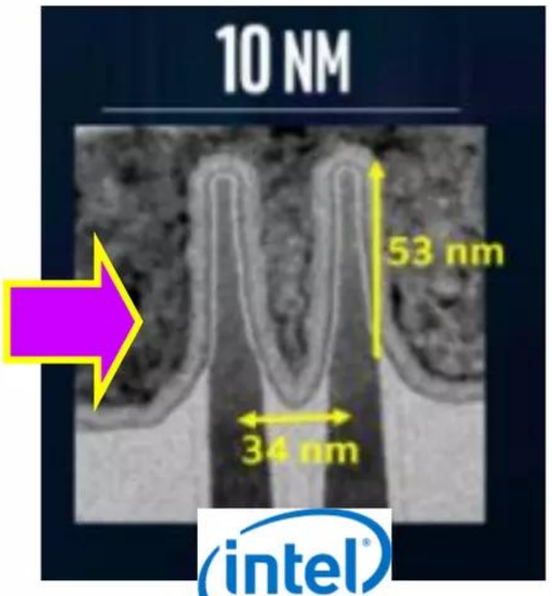
Photo credit: Bell Laboratories (1947)

"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

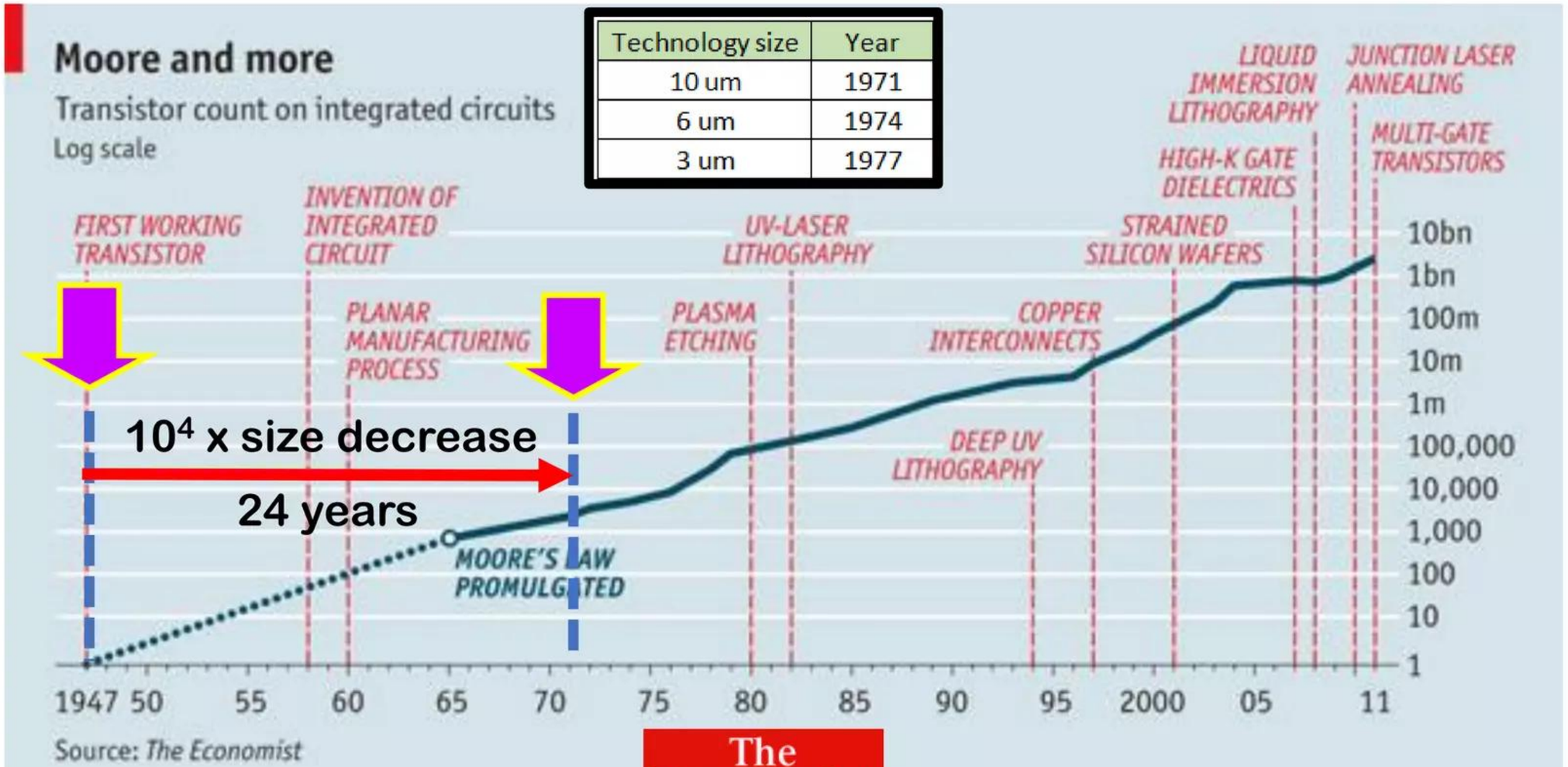


Transistor size shrank by factor of ~10^4 x during first 24 years

Transistor dimensions went from ~0.5” in 1947 prototype to 10 μm by 1971

“Moore's law states that the number of transistors on a microprocessor chip will double every two years or so … which has … meant that the chip's performance will, too. The exponential improvement that the law describes transformed the first crude home computers of the 1970s into sophisticated machines of the 1980s and 1990s and … gave rise to high-speed Internet, smartphones and wired-up cars … becoming prevalent today.” M. Waldrop *Nature* (February 2016)

Technology size	Year
10 um	1971
6 um	1974
3 um	1977



1947 prototype transistor created amplifying gain i.e. $V_{out} > V_{in}$

LENRs: neutron captures release > energy than 'cost' of making neutrons

Transistors and LENR active sites - bedrock components of respective technologies

- First experimental Germanium semiconductor transistor was invented and "ugly" prototype was built at Bell Labs in 1947. First crude handmade device (see prior image) measured ~0.5" in size and was capable of signal amplification, i.e. small changes in input voltage created large changes in output voltage ($V_{out} > V_{in}$). Ratio of V_{out} divided by V_{in} is called the "amplifying gain"; other major commercial use of semiconductor transistors is to function as electrically controlled switches

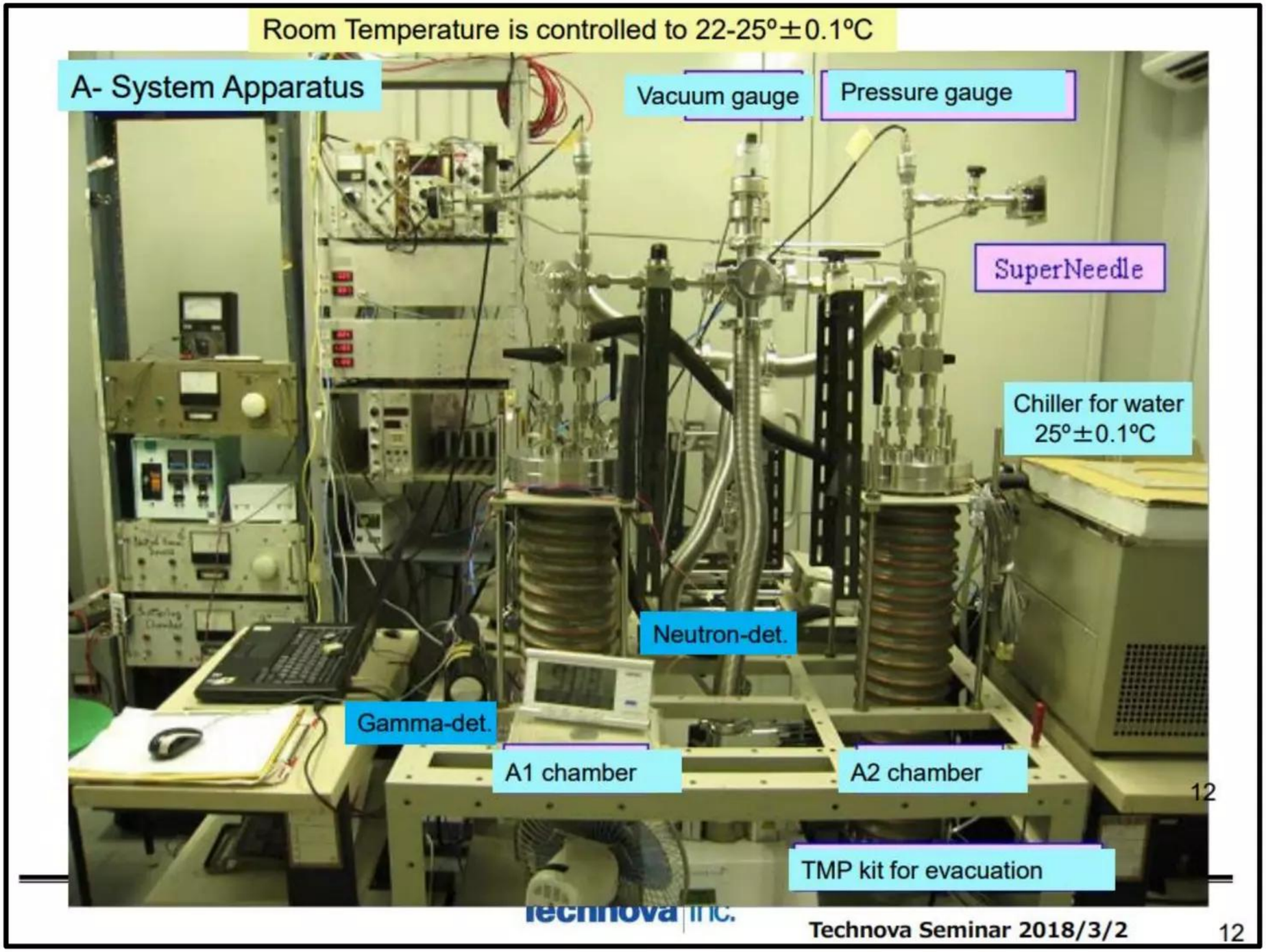
- Analogous to transistors, LENR devices function like an amplifier; but instead of amplifying tiny voltages of electrical input signals, LENRs can effectively amplify input energy. In LENR devices, electromagnetic or chemical energies on scales of electron Volts (eVs) are input and *concentrated* in active sites where ultralow energy (ULE) neutrons are produced via many-body $e + p$ or $e + d$ reactions; ULE neutrons are then locally captured by target fuels. Captures trigger release of stored nuclear binding energy on scale of Mega-electron Volts (MeVs, 10^6 eVs)

- Input energy 'cost' of creating one ULE neutron is 0.78 MeV with Hydrogen and 0.39 MeV with Deuterium. Maximum theoretical upper bound for LENR fuel gain ratio (Energy Stored in Target $Fuel_{released}$ / $Energy_{input}$) will vary by LENR target fuel that captures ULE neutrons. Maximum energetic gain ratio with Deuterium + Lithium fuel is ~34x; gain with Hydrogen for proton source + Nickel fuel is ~12x

“Ugly” prototype of NEDO project LENR reactors circa 2017

Unshielded reactors produced Watts of excess heat without any radiation

Stainless steel reactor functions as resonant electromagnetic cavity for LENR process



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

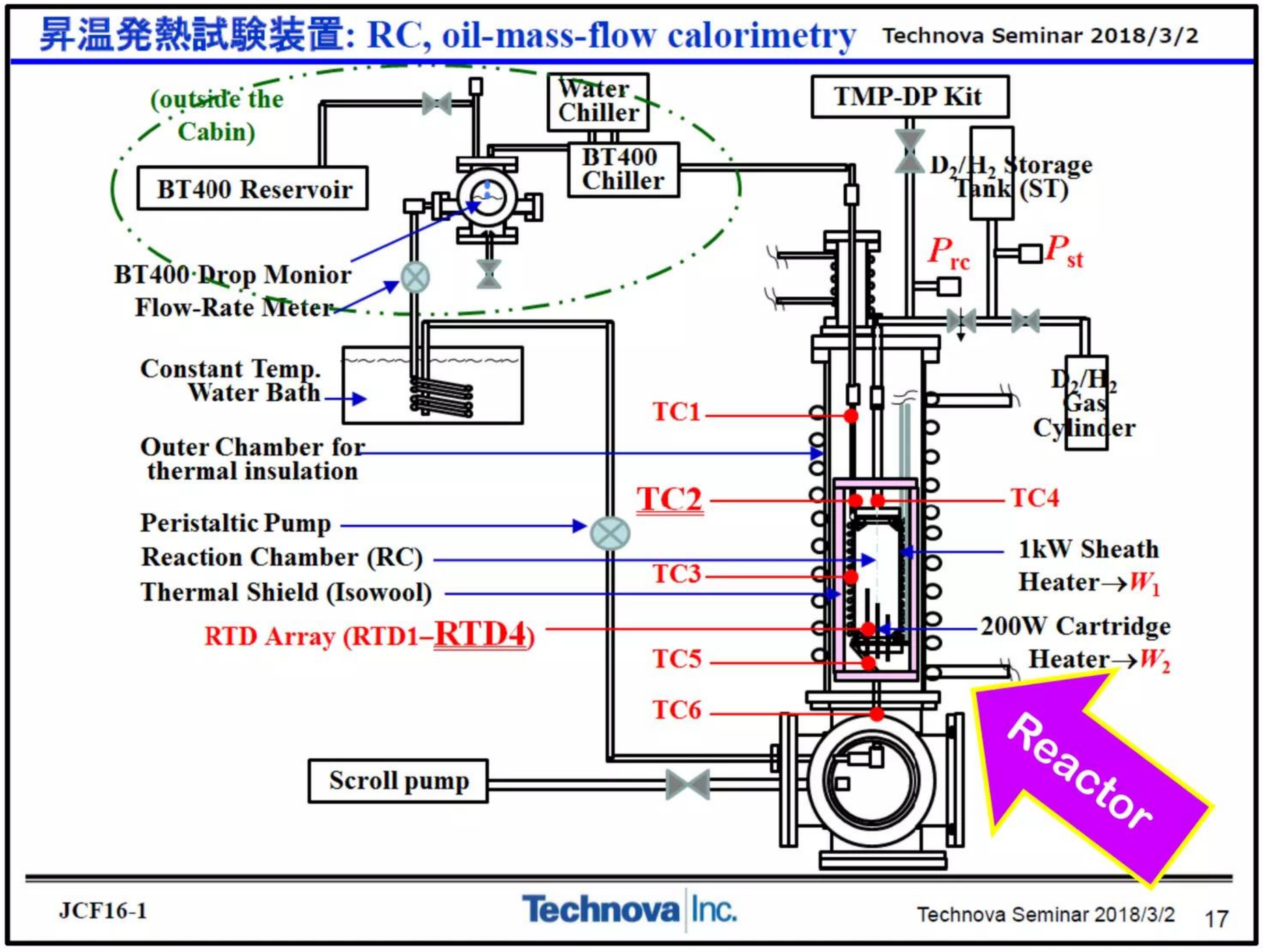
- **NEDO project LENR reactor vessels are resonant electromagnetic (E-M) cavities**: energy input occurs by externally heating metal walls of reaction chambers (RC); this causes emission of broad-spectrum blackbody E-M radiation from inner walls of RC that irradiates LENR materials inside reactors. Surface plasmon electrons associated with surface nanostructures on LENR materials will absorb incident E-M photon energy (esp. from resonant infrared frequencies) and transport it to LENR active sites where ultralow energy neutrons are produced and captured

- 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 heaters could be turned-off. In theory, such a reactor 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

“Ugly” prototype of NEDO project LENR reactor used in 2017

Nanoparticulate materials + H_2 or D_2 + metal-oxide filler in LENR reactor

Input energy provided by electromagnetic radiation coming from heated reactor walls

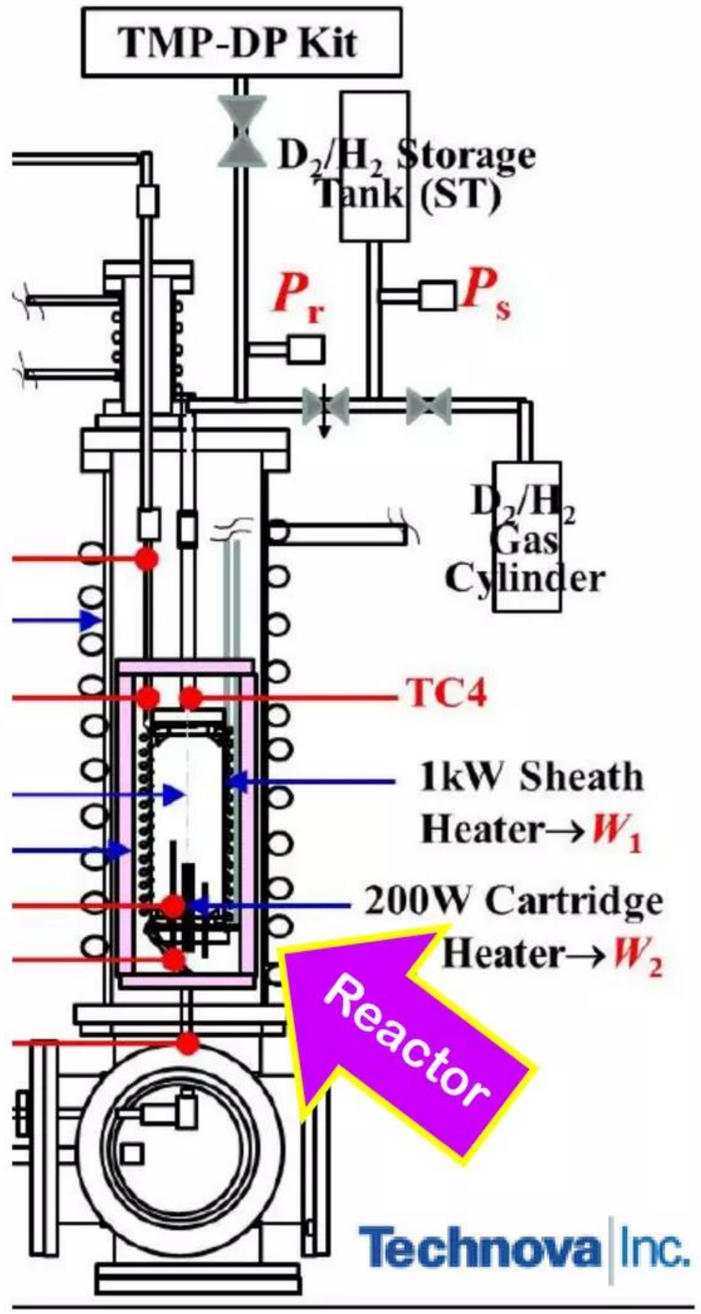


NEDO project utilizes standardized apparatus and methods

Excellent calorimetry accurately measures excess heat production in RC

Generic overview of experimental run after LENR device nanomaterials fabrication

1. Non-destructively characterize LENR device materials
2. Place LENR materials + filler in reaction chamber (RC)
3. 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 is sealed); measure excess heat production via calorimetry (is negligible @ room temp)
4. Use external heating to warm-up reaction chamber to working temperatures of 150 - 450º C (avg. 200 - 300)
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 run
6. Stop experiment; remove all sample materials from RC
7. Post-experiment: analyze LENR device nanomaterials

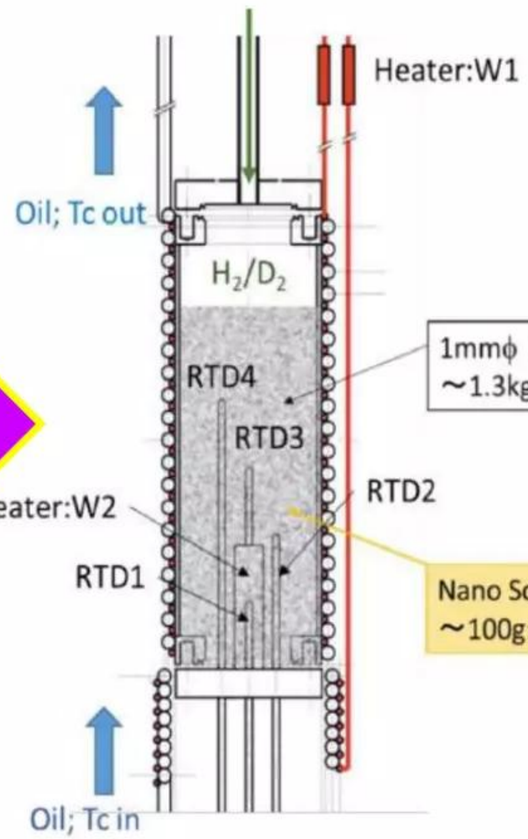


“Ugly” prototype of NEDO project LENR reactor used in 2017

Nanocomposite LENR target fuel materials and filler in reaction chamber

~100⁺ grams of device nanoparticles mixed with 1,300 gms. 1 mm Zirconia filler beads

Reaction Chamber (500 cc) and filler + sample



Reactor

1mmϕ Zirconia Beads; ~1.3kg

1mmϕ beads

~1,300g

Nano Scale Sample; ~100g: PNZ, CNZ, etc...

CNZ6s sample

~100g

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Model: sample PNZ7k Pd_1/Ni_7 nanoparticle loading with D(d^+)

D(H)/Metal-atom ratio > 0.80 for many-body d^+ islands to form on surface

Widom-Larsen theory: LENR active sites form spontaneously on nanoparticle surfaces

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				

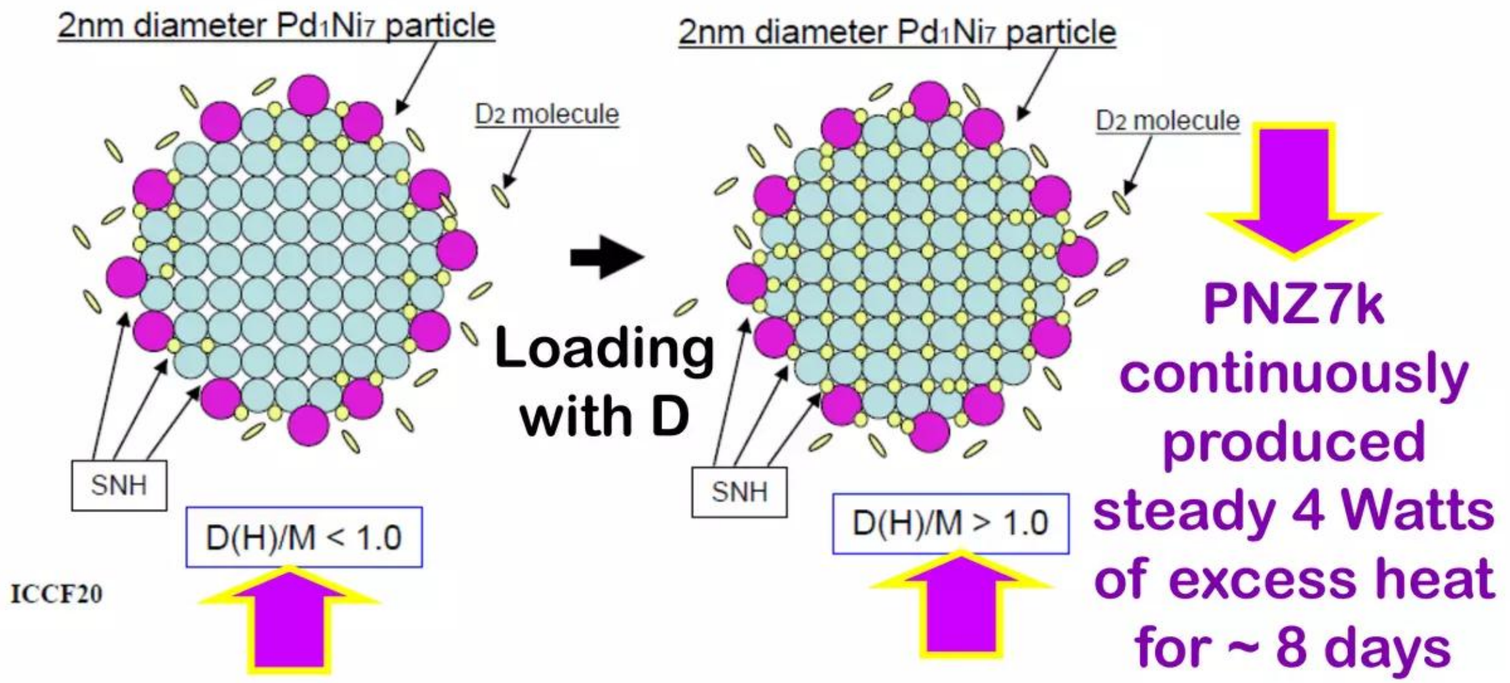
4 Watts

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)

D(H)-atom
Ni-atom; r_0 = 0.138 nm
Pd-atom; r_0 =0.152 nm (or Cu)

D(H)-atom
Ni-atom; r_0 = 0.138 nm
Pd-atom; r_0 =0.152 nm (or Cu)



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Est. max. cost of NEDO LENR project US$ 54 million to date

Achieved: ~80% reproducibility, Watts of excess heat & TRL-4 in 2.5 years

- For previous 29 years before recent public release of NEDO LENR project's experimental results, production of calorimetrically measured excess heat during vast majority of laboratory experiments with LENR devices was only a hit-or-miss 1-in-10 proposition, at best. Excess heat measurable with accurate calorimetry was produced in small % of such experiments; when observed, it typically ranged from 10 - 500 milliwatts (*rarely* above 1 Watt or more) and was usually produced for periods ranging from few hours to at most several days

- While Mitsubishi Heavy Industries and others published many reports about excellent experiments in which microscopic amounts of LENR transmutation products were produced 90^{+}% of the time, creating substantial amounts of macroscopic excess heat remained an elusive goal. Consequently, as far as commercializing LENRs for power generation, continued R&D efforts to greatly improve reproducibility and boost excess heat stagnated at TRL-3 for > 10 years

- NEDO RFP for LENR project announced July 2015; participants were selected shortly thereafter. LENR was one of 10 projects funded by NEDO for total of US$ 27 million per year. Although budget details never released, assume 80% of funding went for LENRs: 27 x 0.80 = US$ 21.6 million/year. Assuming NEDO funding continued at same rate until now (~ 2.5 years have elapsed), 21.6 x 2.5 = US$ 54 million (estimated upper bound) was spent so far. For this sum, went from TRL-3 → TRL-4 and LENR excess heat production boosted by >1,000x (10^3)

How did NEDO accomplish so much with $54M in 2.5 years?

Answer: leveraged W-L theory, nanotechnology, and materials science

- There is no discussion in NEDO project reports about LENR active sites in context of NP device fabrication and maximization of excess heat production. Researchers may have decided not to focus on active site concepts or are actively researching them but instead keeping such information confidential
- If one has no model for active sites and/or is not trying to optimize them, then one must perforce rely on their spontaneous random formation on LENR device material surfaces. Given this limitation and following precepts of W-L theory, how would one attempt to increase device reproducibility and heat production?
- Answer: stop using planar bulk metallic devices and develop well-engineered hydride-forming metallic nanoparticles (NPs) mixed with larger metal-oxide "filler" particles in H_2 or D_2 gas reactors. Advantages: (1) NPs and fillers vastly increase working surface area inside reactors (boosts total area by > 10^6 x vs. planar bulk); (2) use of small-dimension NPs maximizes surface/volume ratio for particles; helps further maximize area for active sites to form and greatly improves crucial H_2/D_2 gas loading of LENR materials to key M/H ratios > 0.80. Wittingly or unwittingly, by employing this strategy NEDO project scientists effectively followed experimental guidance provided by Widom-Larsen theory
- Add Nickel (Ni) to NPs: educated materials science 'guess' based on knowing about 1990s-era Italian planar Ni/H_2 gas excess heat results (MJ over months)

LENRs are radiation-free and far superior to fission or fusion

NEDO project achieved TRL-4 and demonstrated that LENRs can produce multiple Watts of excess heat from nanocomposite multi-metal devices without emission of deadly fluxes of energetic neutron or gamma radiation **--- it is shown to be truly safe nuclear technology**

Further R&D tasks beyond TRL-4: finish nanotech engineering for Widom-Larsen LENR active sites, optimize array of device materials & target fuels, and scale-up device thermal output and operating lifetimes

Credit: Getty Images

Still relying on spontaneous random formation of active sites

Next step in thermal output scale-up: purpose-built active site precursors

- Nanocomposite LENR devices in Japanese NEDO industry-academia-government R&D project produced enough cumulative excess heat to boil much more than a "cup of water," thus decisively refuting LENR naysayers
- NEDO results finally achieved reasonable experimental reproducibility for Watt-levels of excess heat; however, their experimental devices still rely on spontaneous *random* formation of active sites in LENR device materials
- There is no doubt that present levels of NEDO device performance can be further improved with even better fabrication methods and yet-to-be-tested types of LENR device materials; that work is presently underway in Japan
- Lattice believes further substantial improvements in device reproducibility and scale-up of excess heat will require mastery of design, fabrication, and emplacement of device nanostructures that are precursors to Widom-Larsen theory LENR active sites. Achieving this goal should result in 100% reliable LENR devices where amount of heat production is very predictable
- Developing capability to fabricate 100% reliable LENR active sites along with target fuels should enable rapid excess heat scale-up to at least 10 kW

LENRs and the future of CO_2-free electric power generation

5 - 10 kwh LENR-based power systems revolutionize energy production

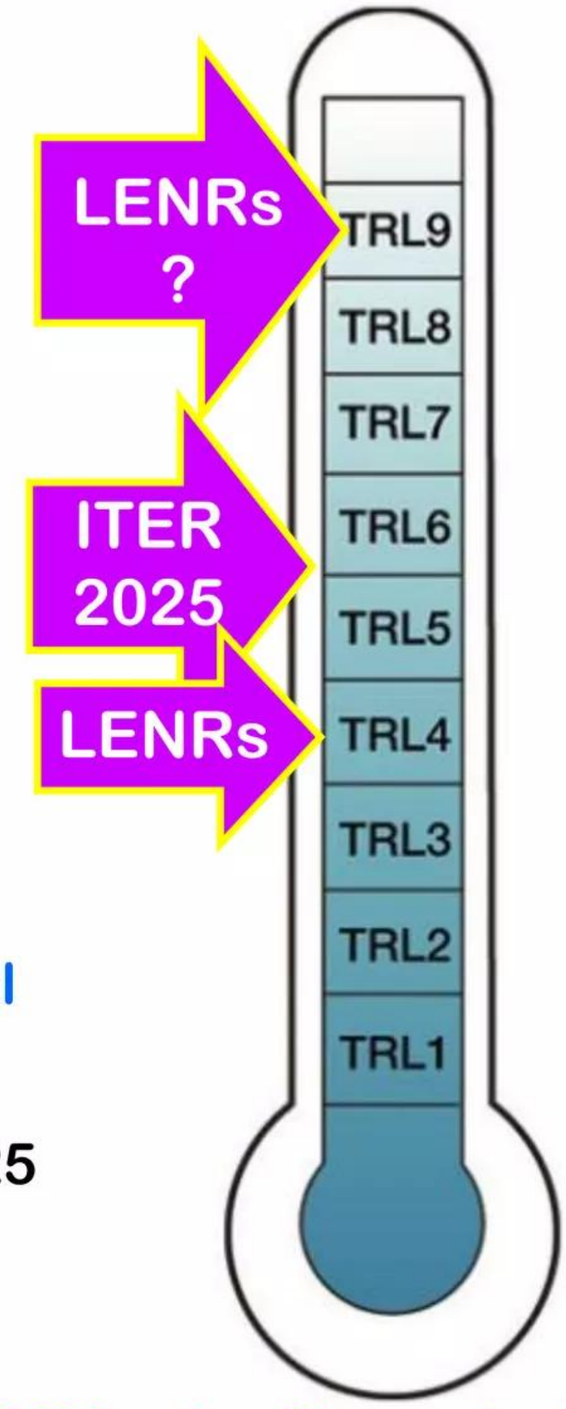
Megawatt-output LENR power generation systems unnecessary for revolution

- **At electric power outputs of only 5 - 10 kwh:** modular LENR-based distributed power generation systems providing combined heat and electricity (CHP) could probably satisfy requirements of most urban and rural homes and small businesses worldwide, including ~1.2 billion presently powerless rural people
- **At electric power outputs of 60 - 200 kwh:** LENR-based powertrains could begin to propel all-electric or hybrid vehicles, breaking oil's stranglehold on transportation; also provide high-quality heat for many industrial processes
- Although they could probably be designed and built, megawatt LENR power plants are not required to revolutionize production of CO_2-free green energy
- If broad deployment of small-scale distributed LENR CHP power generation could be achieved, nowhere near as many large fossil-fueled and/or fission power plants would have to be built to reliably supply low-cost electricity to regional grids that demand 99^{+}% uptime availability. In the future, grid-based centralized power generation could gradually be displaced by vast numbers of smaller, distributed CO_2-free renewable and LENR-based power systems

Large increases in R&D spending on LENRs are warranted

LENR technology at TRL-4; investing $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 most ~ US$250 million; LENRs nevertheless advanced up to TRL-3
- In 2.5 years since 2015, cumulative NEDO LENR project spending probably was at most US$ 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 < 300 people worldwide. Total R&D funding since 1989 thus likely < US$ 350 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



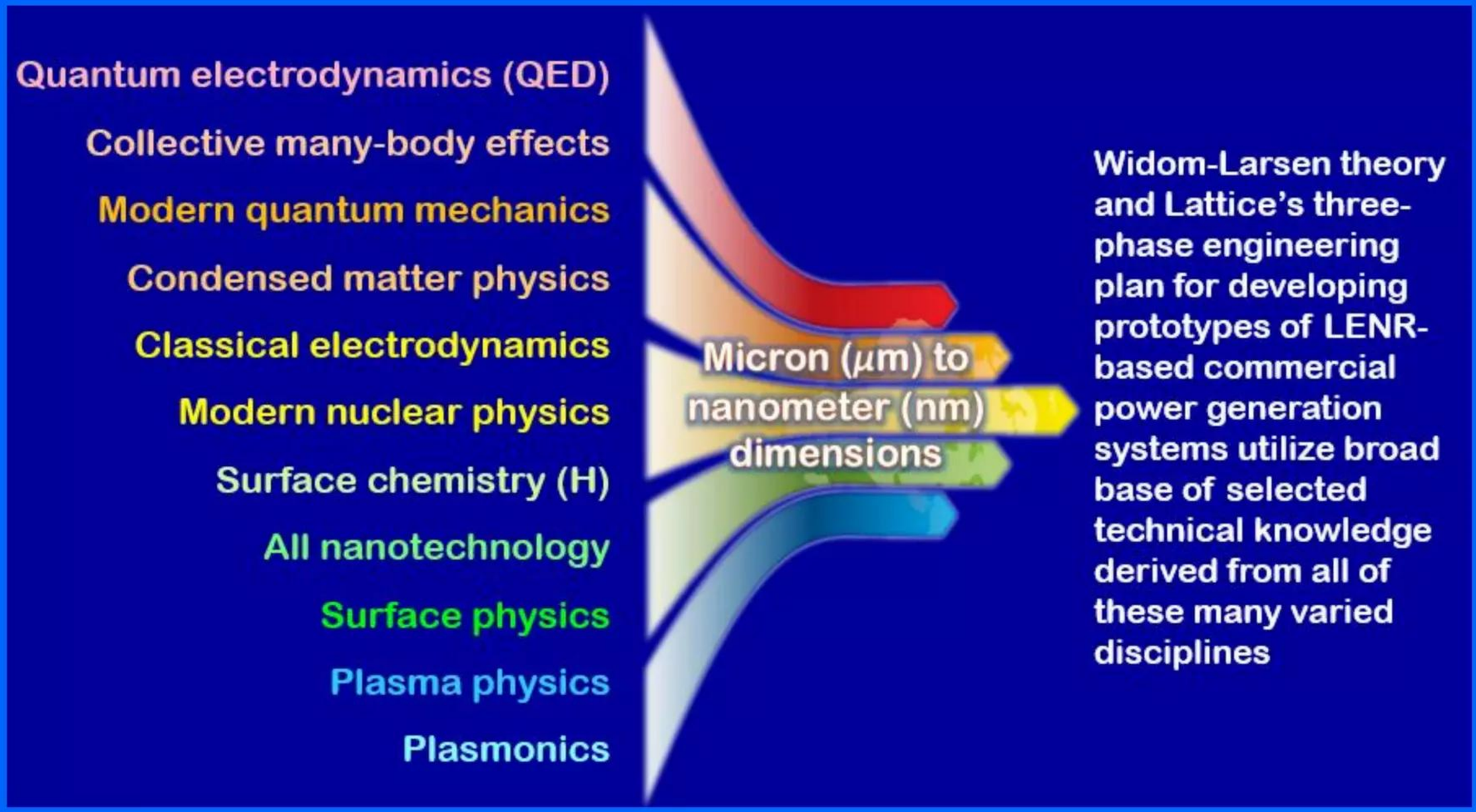
http://www-naweb.iaea.org/napc/physics/meetings/TM49530/website/talks/May%2012%20Sessions/Sagara_A.pdf

LENRs are an incredibly interdisciplinary area of science

Resisted understanding until Widom-Larsen put all the pieces together

Nanometer-to-micron scale many-body collective effects enable the 'impossible'

Scientists have observed LENRs for 100 years - didn't connect anomalies to nuclear process



Lattice LENR device engineering plan has three key phases:

1. Achieve 100% reproducible fabrication of LENR active site precursors

2. Scale-up device heat output: increasing #s of active sites per unit area/volume

3. Select & integrate energy conversion subsystems: develop power generation products

- Lattice's approach to active site engineering is nanocentric, interdisciplinary, and guided by various proprietary insights enabled by Widom-Larsen theory of LENRs, as well as relevant applied knowledge derived from nuclear physics, materials science, plasmonics, nanotechnology & aspects of surface catalysis
- Once low-cost, high-volume nanofabrication of LENR active site precursors is achieved, thermal output of LENR-based heat sources could then be scaled-up either by: (1) fabricating larger area-densities of proprietary nanostructures that 100% reliably form active sites on LENR device surfaces; or (2) injecting larger quantities of specially designed target fuel nanoparticles into larger-volume reaction chambers utilizing turbulent dusty plasmas, with or without presence of well-controlled, spatially organized (cylindrical) magnetic fields
- Variety of different, off-the-shelf energy conversion technologies could then be integrated with commercial versions of LENR-based thermal sources. These include: thermophotovoltaic; thermoelectric; steam engines; various Rankine cycle steam turbines; Brayton cycle gas turbines, simple boilers, etc. Other more speculative integration possibilities include new types of direct energy conversion technologies that are still in very early TRL stages of development

Use electronics business strategies to penetrate key markets

Maximize total unit volumes & leverage huge energy density advantages

Certain aspects of semiconductor industry and LENR technologies are similar

- **LENR products should exploit experience curve effects to reduce manufacturing costs.** Same as successful market penetration strategies utilized by electronics manufacturers; e.g., microprocessors, memory chips, PCs, and smartphones
- **As product manufacturing experience accumulates and internal build costs are progressively reduced, leverage longer operating life and huge energy density advantages of LENRs** (thousands of times larger than any chemical technology)
- **Price LENR-based systems to drastically undercut price/performance features provided by competing electrochemical battery energy storage systems and fission or combustion-based power generation systems.** Strategy can be used to attack portable, stationary, mobile, and MW-scale commercial power generation markets
- **Small-scale LENR systems might seem to be light years away from being able to compete with huge 500 - 1,500 MW coal-fired and Uranium-fission power plant behemoths. However, please recall history of personal computers versus large mainframes.** When PCs first introduced over 40 years ago, mainframe computer manufacturers regarded them as just toys, information processing jokes of little consequence. Less than 10 years later, mainframe companies weren't laughing any more. **Today, except for just a handful of hardy survivors like IBM, mainframe and minicomputer 'dinosaurs' have disappeared; replaced by microprocessor arrays**

Further info about Japanese NEDO project's reported results

Purplish hyperlinks below are 'live' as well as in SlideShare PowerPoints

"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

"January 2018: project report released - summarized progress in Japanese government-funded NEDO R&D in LENRs for Oct. 2015 thru Oct. 2017. Project scientists reported good progress in developing nanocomposite LENR devices for use as powerful heat sources"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-lenr-project-reported-good-progress-in-excess-heat-production-and-device-fabrication-jan-27-2018

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