The Trajectory of Recent Solid State Fusion Results

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Abstract

Both NASA and Google have explored and funded Low Energy Nuclear Reactions (LENR) *aka* Solid-State Fusion or Lattice Confinement Fusion (LCF) research. NASA has funded efforts since 1989, and Google Research began in 2014. Google, and researchers initially-funded by Google, published significant scientific papers in *Nature*, *Nature Communications,* the *Journal of Applied Physics* along with two issued patents. NASA began a significant set of LENR-triggering programs in 2012 resulting in papers in *Physical Review C*, the *Journal of Electroanalytical Chemistry* and the *Journal of Condensed Matter Nuclear Science*. The *Phys Rev C* papers led to LCF driven by Inertial Electrostatic Confinement (IEC) leading to a multi-state, commercialized neutron generator by Astral Systems, Ltd. in the UK.

NASA and Google engaged researchers across fields of nuclear physics, chemistry, electrochemistry, material science and more. NASA built upon early novel gas pumping experiments followed by the patented work of the US Navy SPAWAR (US 8,419,919, "System and Method to Generate Particles") and scaling experiments with the Naval Surface Warfare Centers. Google supported researchers at Lawrence Berkeley National Laboratory (LBNL), the University of British Columbia (UBC), MIT and others. This resulted in patent applications and two granted patents (US 10264661B2, "Target structure for enhanced electron screening" and US 10566094B2 "Enhanced electron screening through plasmon oscillations").

These separate efforts, unknown to the researchers at the time, provided the impetus for the DoE ARPA-E LENR program followed by the DARPA DSO "Mechanisms for Amplification of Fusion Reaction Rates in Solids" (MARRS) program. This document mentions the overlapping NASA and Google Research efforts in plasma loading and electron screening while emphasizing the results of the latest paper in *Nature Communications*. The papers and patents cited are listed.

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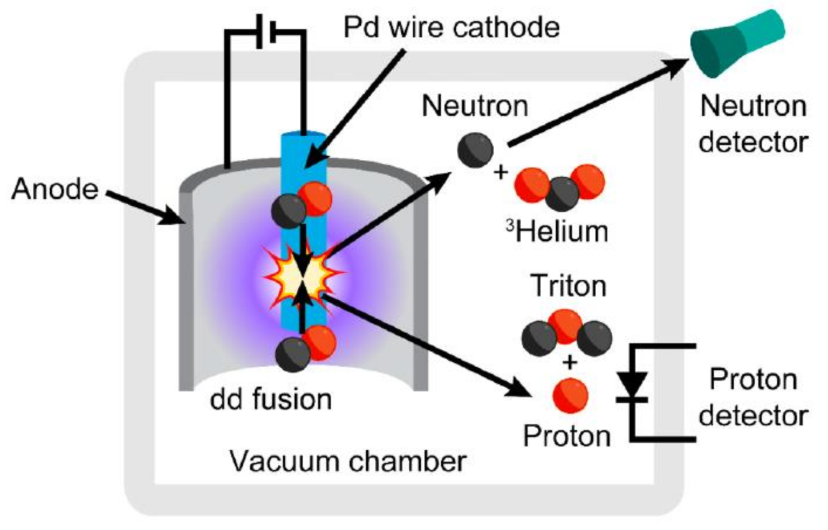
NASA/TM-20260007648

Overview

1. **Recent Related Solid State Fusion Nature Family Papers**
   1. "Electrochemical loading enhances deuterium fusion rates in a metal target", *Nature*, August 2025
      1. Chen, Maiwald, Schauer, Issinski, Garcia, Oldford, Egoriti, Higashino, Vakili, Wen, Koh, Schenkel, Stolar, Brown, & Berlinguett
   2. "Enhanced nuclear fusion in the sub-keV energy regime", *Nature Communications*, July 2026
      1. Karahadian, Colborne, Persaud, Schenkel & Munday
2. **Related Work**
   1. NASA glow and plasma discharge
   2. Electrochemical co-deposition
   3. Bremsstrahlung-photodissociation of deuterons and neutron heating
3. **Next Steps**
   1. Look for boosted neutrons as observed by NASA (*Phys. Rev C*., April 2020)
   2. Ratio of exit channels: D(d,n)^{3}He/D(d,p)T ratio: *e.g.* conventional fusion 50:50
   3. Review electron screening findings and equations
      1. 0.25 – 6.5 keV center-of-mass deuteron energies
      2. "A central experimental finding of this work is the emergence of a pronounced plateau—corresponding to a finite yield floor—in the deuterium–deuterium fusion yield below ~2 keV in metallic hydrides, in stark contrast to the expected exponential suppression at low energies. This behavior is observed reproducibly in both Pd and Ti hosts."
         ["Enhanced nuclear fusion in the sub-keV energy regime", *Nature*, July 2026]
   4. Cross-compare related papers and patent filings

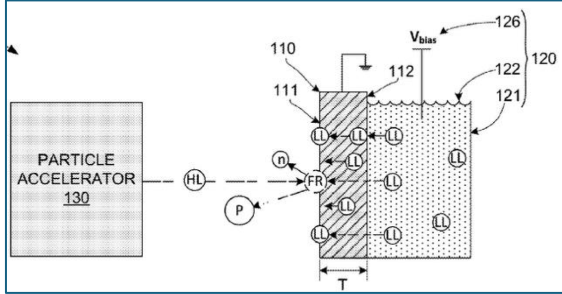
Lattice Confinement Fusion

Plasma discharge and electrolytic loading

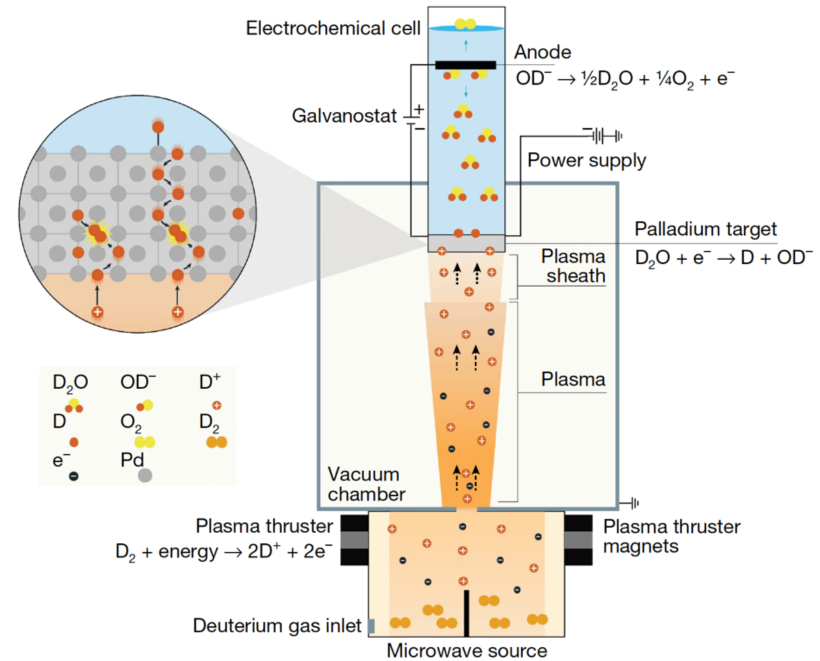


"Revisiting the cold case of cold fusion", *Nature*, May 2019
"Investigation of light ion fusion reactions with plasma discharges", *J. Applied Physics*, November 2019
Google Research funded 2015-2018

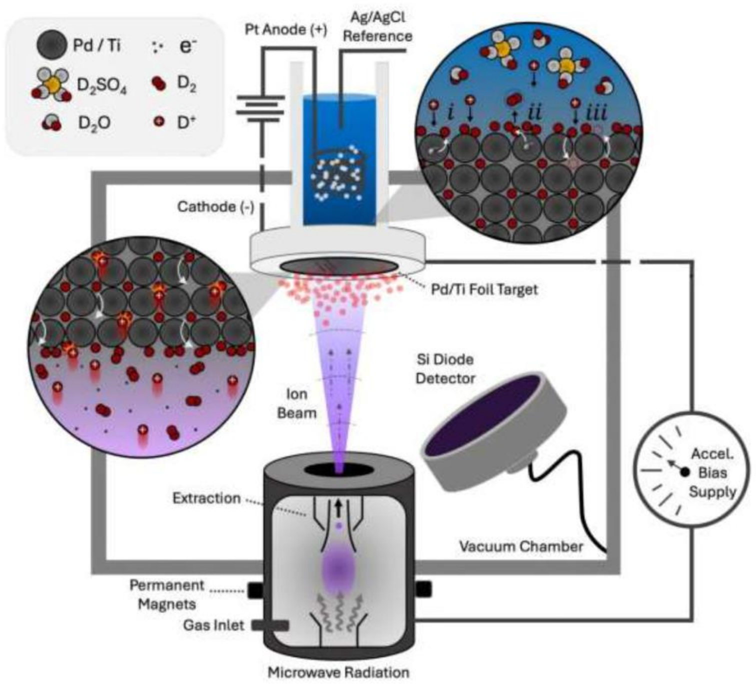
Like Google/LBNL, NASA GRC conducted glow/plasma discharge experiments at the same time, but was SBU restricted to prevent discussions.
"Plasma Reactor Summary", *NASA TM-2020-220344,* May 2020,
"Plasma Loading and Nuclear Reactions in Condensed Matter, NASA TM-2022-0009864, July 2022
"The History of LENR Research at NASA Glenn Research Center", *JCMNS*, 2024
NASA GRC/SMD funded 2014 – 2020+



US Application 2021/01511206 A1 "Apparatus and Method for Sourcing Fusion Reaction Products" (Assigned UBC/Google/UCal/DoE, ***Abandoned***)



"Electrochemical loading enhances deuterium fusion rates in a metal target", *Nature*, August 2025. funding: Thistledown Foundation, Nat. Sci. & Eng. Res. Council of Can., Can. Foundation for Innov. and Can. Inst. for Adv. Res.



"Enhanced nuclear fusion in the sub-keV energy regime", *Nature Communications*, July 2026
ARPA-E funded 2023-2025

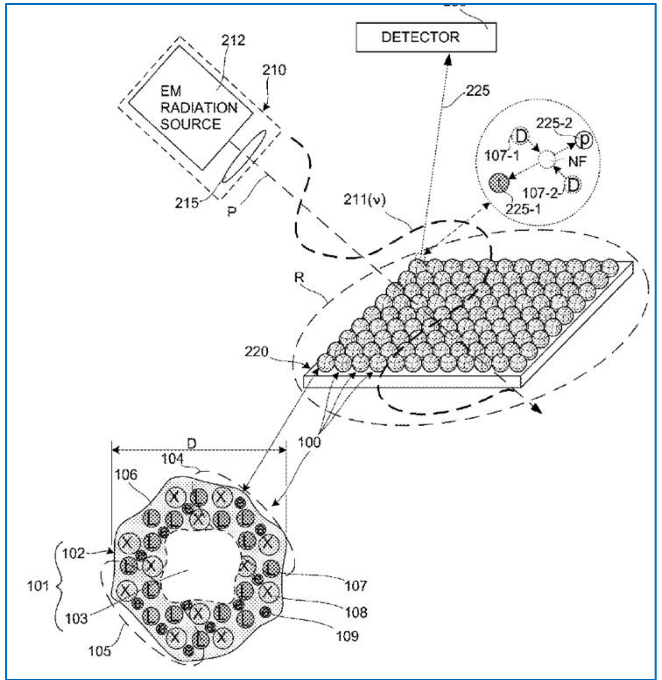
- Neutron and proton data
- Si Diode charged particle detection
  - plasma EMI limited
- Electron Screening data
- Screening enhancement equations
- More accurate *U_e < 5 keV*
- ? DD fusion ratio: *T,p* vs *^{3}He,n*
- ? Boosted fusion neutrons

Lattice Confinement Fusion

Significance

1. **More Accurate Low Energy Fusion Experiments**
    1. Lattice Confinement Fusion/Solid State Fusion
    2. Electron Screening and Equations
        1. Increases nuclear reactions 10^{18} times over Gamow Factor c.m. << 5 keV
        2. Apply to INL FROG, UofR TriForce and other nascent fusion codes
2. **Nuclear Diagnostics**
    1. Eljen EJ-309, *neutron spectrometer*
    2. Silicon Diode Detector, *charged particles*
3. **Data**
    1. LBNL or UC Davis boosted neutrons as observed by NASA?
        1. Re-process data above 3 MeV
        2. Need calibration neutron data for spectrum unfolding
    2. UC Davis fusion proton, neutron ratio?
4. **Algorithms**
    1. CAEN Digitizer Firmware
    2. Pulse Shape Discrimination
        1. EMI/gamma discrimination
    3. Neutron unfolding
5. **Publications**
    1. *Nature, 2019, 2025,*
    2. *Journal of Applied Physics, 2019*
    3. *Nature Communications, 2026*
    4. *Patents and Patent Applications, Google, 2017, 2019, 2021*
6. **Significance**
    1. *Support for LENR/Solid State Fusion/LCF patents*
    2. *Support for LENR/Solid State Fusion/LCF Nature Family publications*
    3. *Support fusion modeling of hot and condensed matter cold plasmas*

Funded and Assigned to Google



Provisional US Application 15/668,436 (Aug 3, 2017)
US Application 2019/0043624 A1 (Feb 7, 2019)
US 10,566,094 B2 (Feb 18, 2020)
"Enhanced Electron Screening through plasmon oscillations"

Provisional US Application 15/668,499 (Aug 3, 2017)
US Application 2019/0045617 A1 (Feb 7,2019)
US 10,264,661 B2 (Apr 16, 2019)
"Target Structure for Enhanced Electron Screening"

Lattice Confinement Fusion

Cited Papers

Support	**Paper/Access**
Google:	"Revisiting the cold case of cold fusion". *Nature*, **570**, May 27, 2019 https://doi.org/10.1038/s41586-019-1256-6
Google:	"Investigation of light ion fusion reactions with plasma discharges", *JAP*, **126**(20) November 25, 2019 https://doi.org/10.1063/1.5109445
NASA:	"Plasma Reactor Summary", *NASA*, **TM-2020-220344**, May 11, 2020 https://ntrs.nasa.gov/api/citations/20200004338/downloads/TM-2020-220344.pdf NASA TM-2020-220344
NASA:	"Novel Nuclear Reactions Observed in Bremsstrahlung-Irradiated Deuterated Metals", *Phys. Rev. C*, **101**, 044610 April 20, 2020 https://journals.aps.org/prc/abstract/10.1103/PhysRevC.101.044610
NASA:	"Electrolytic co-deposition neutron production measured by bubble detectors", *Jelechem*, **882**, 115024, January 21, 2021 http://dx.doi.org/10.1016/j.jelechem.2021.115024
NASA:	"Plasma Loading and Nuclear Reactions in Condensed Matter", *ICCF-24 LENR Short Course*, July 23, 2022, *NASA*, **TM-2022-0009864** https://ntrs.nasa.gov/api/citations/20220009864/downloads/Plasma%20Loading%20narrated%20presentation.pdf https://www.youtube.com/watch?v=_4QBbgJyk7w
NASA:	"The History of LENR Research at NASA Glenn Research Center", *JCMNS*, **38**, December 5, 2023 https://doi.org/10.70923/001c.124937
Canada:	"Electrochemical loading enhances deuterium fusion rates in a metal target", *Nature*, **644,** August 21, 2025. https://doi.org/10.1038/s41586-025-09042-7
ARPA-E:	"Enhanced nuclear fusion in the sub-keV energy regime", *Nature Communications*, July 18, 2026 https://doi.org/10.1038/s41467-026-74421-1

Journal Impact Factors

Nature:	56.1
Nature Communications:	~15.7
Journal of Electroanalytical Chemistry (Jelechem):	4.6
Physical Review C (Phys. Rev. C):	3.3
Journal of Applied Physics (JAP):	2.7
Journal of Condensed Matter Nuclear Science (JCMNS):	0.3

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Cited Patents and Patent Application

National Aeronautics and Space Administration

System and Method for generating particles

US8419919B1
United States

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Inventor: Pamela A. Boss, Frank E. Gordon, Stanislaw Szpak, Lawrence Parker Galloway Forsley

Current Assignee : US Department of Navy , JWK International Corp

Worldwide applications

2007 · US

Issued 2013

Application US11/859,499 events

- 2003-03-11 · Assigned to JWK INTERNATIONAL CORPORATION
- **2007-09-21** · Application filed by JWK International Corp, US Department of Navy
- **2007-09-21** · Priority to US11/859,499
- 2013-03-11 · Assigned to JWK INTERNATIONAL CORPORATION
- **2013-04-16** · Application granted
- **2013-04-16** · Publication of US8419919B1
- **Status** · Expired - Fee Related
- **2030-07-23** · Adjusted expiration

Target structure for enhanced electron screening

US10264661B2
United States

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Inventor: David K. Fork, Jeremy N. Munday, Tarun Narayan, Joseph B. Murray

Current Assignee : Google LLC , University of Maryland College Park

Worldwide applications

2017 · US

Issued 2019

Application US15/668,499 events

- **2017-08-03** · Application filed by Google LLC, University of Maryland College Park
- **2017-08-03** · Priority to US15/668,499
- 2017-08-03 · Assigned to UNIVERSITY OF MARYLAND, COLLEGE PARK, GOOGLE INC.
- 2017-10-20 · Assigned to GOOGLE LLC
- **2019-02-07** · Publication of US20190045617A1
- **2019-04-16** · Application granted
- **2019-04-16** · Publication of US10264661B2
- **Status** · Active
- **2037-10-21** · Adjusted expiration

Enhanced electron screening through plasmon oscillations

US10566094B2
United States

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Inventor: David K. Fork, Jeremy N. Munday, Tarun Narayan, Joseph B. Murray

Current Assignee : Google LLC , University of Maryland College Park

Worldwide applications

2017 · US

Issued 2020

Application US15/668,436 events

- **2017-08-03** · Application filed by Google LLC, University of Maryland College Park
- **2017-08-03** · Priority to US15/668,436
- 2017-08-03 · Assigned to UNIVERSITY OF MARYLAND, COLLEGE PARK, GOOGLE INC.
- 2017-10-20 · Assigned to GOOGLE LLC
- **2019-02-07** · Publication of US20190043624A1
- **2020-02-18** · Application granted
- **2020-02-18** · Publication of US10566094B2
- **Status** · Active
- **2038-05-05** · Adjusted expiration

Apparatus And Method For Sourcing Fusion Reaction Products

US20210151206A1
United States

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Inventor: Thomas Schenkel, Ross Koningstein, Peter Seidl, Arun Persaud, Qing Ji, David K. Fork, Matthew D. Trevithick, Curtis Berlinguette, Philip A. Schauer, Benjamin P. MacLeod

Current Assignee : University of British Columbia , Google LLC , University of California San Diego UCSD

Worldwide applications

2020 · US

Abandoned 2021

Application US16/806,760 events

- **2020-03-02** · Application filed by University of British Columbia, Google LLC, University of California San Diego UCSD
- **2020-03-02** · Priority to US16/806,760
- 2020-03-02 · Assigned to THE UNIVERSITY OF BRITISH COLUMBIA
- 2020-03-02 · Assigned to GOOGLE INC.
- 2020-12-07 · Assigned to THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
- 2020-12-16 · Assigned to UNITED STATES DEPARTMENT OF ENERGY
- **2021-05-20** · Publication of US20210151206A1
- **Status** · Abandoned

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