The Fork in the Road to Electric Power From Fusion

Lawrenceville Plasma Physics, Inc. (LPP)

Peter Lobner, 1 February 2021

Lawrenceville Plasma Physics was founded in 2003 by Eric Lerner in Middlesex, NJ. LPP's website is here: https://lppfusion.com

The firm has been developing a machine called "Fusion Focus" that is based on two principles;

- Pulsed "dense plasma focus" (DPF)
- Aneutronic hydrogen (proton) / boron-11 fusion reaction

$$^{1}p + ^{11}B \rightarrow 3\ ^{4}He + 8.7\ MeV$$

Energy generated by p-B11 fusion is carried off by three positively charged alpha particles, which creates an opportunity for direct conversion into electricity.

In 2006, LPP filed patent US7482607B2 for their DPF concept. The patent was granted in 2009. Patent Figure 7 shows the general arrangement of the DPF device. Key components are the many cathodes (112), a hollow anode (114), an insulator installed between the anode and cathode (116) and a helical coil (122).

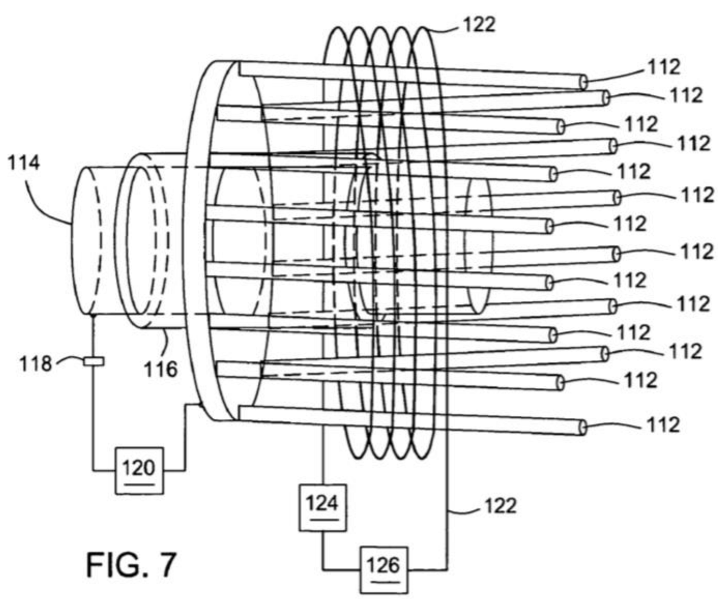
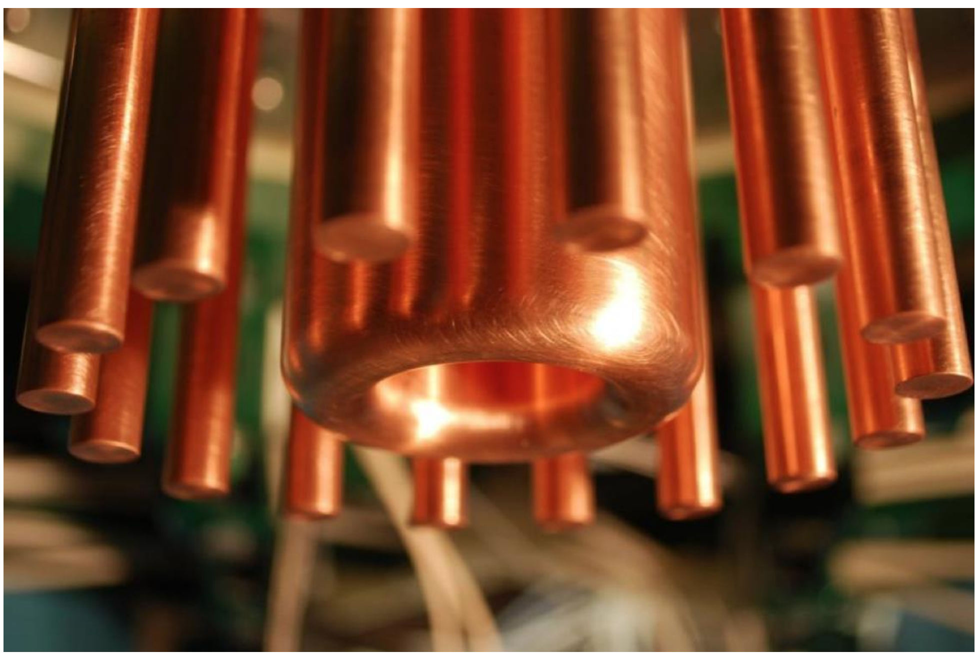


FIG. 7

Operation of the DPF device is described in the patent as follows:

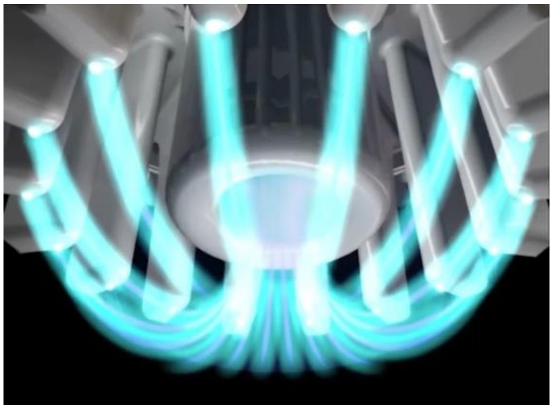
> "The present invention includes an apparatus and method for ….. the generation of fusion energy and the conversion of the energy into electrical energy including an anode and a cathode positioned coaxially and at least partially within a reaction chamber that imparts an angular momentum to a plasmoid. The angular momentum may be imparted through the cathode having a helical twist; a helical coil about the cathode or a combination thereof. The anode has an anode radius and the cathode has a cathode radius that imparts a high magnetic field. The reaction chamber contains a gas and an electronic discharge source in electrical communication with the anode and the cathode. As a result of an electronic discharge a dense, magnetically confined, plasmoid is created about the anode and emits one or more particles."

The actual anode and cathode configuration in the Fusion Focus-1 device built by LPP implements the design in the patent.

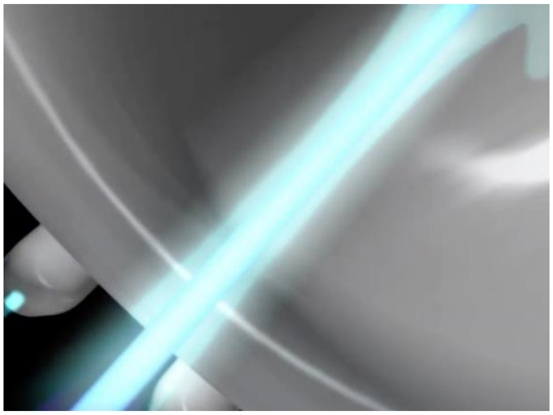


Fusion Focus 1 hollow anode and cathodes. Source: LPP

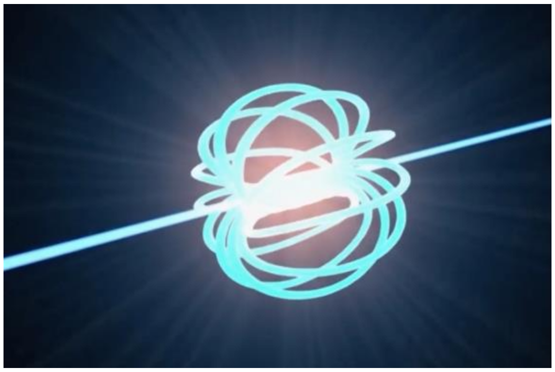
The firm began experiments with deuterium in 2009. Fusion Focus takes advantage of certain known plasma instabilities in their process for generating a fusion-producing plasmoid. The machine is in a vacuum chamber into which the fuel (hydrogen and boron-11) has been introduced. The basic process for each pulse is shown in the following sequence of graphics.



After a 2 microsecond, 1 mega amp pulse has been initiated, plasma filaments (dense vortices) form between the cathodes and the hollow anode.



The plasma filaments merge and form a single, dense plasma strand that "fountains" into the hollow anode, creating a strong pinch and heating the plasma.



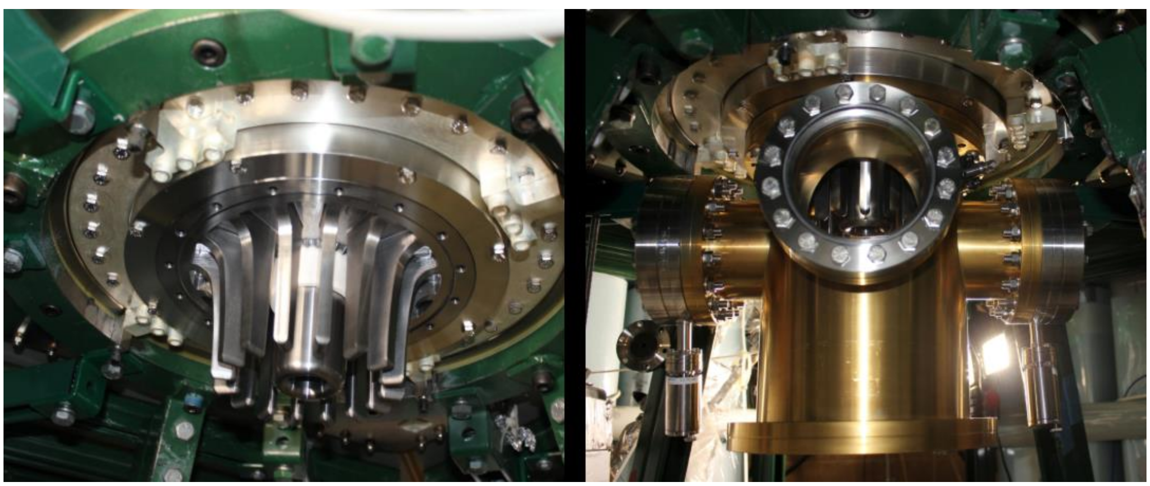
The single strand rapidly develops a kink instability that coils and forms this type of plasmoid configuration that can reach a temperature of 260 keV (about 3 billion °C), initiate p-B11 fusion, and generates X-rays and an ion beam that can be harvested for electricity.

The above three graphics are from the short LPP video, "How Focus Fusion Works," (5:13 minutes), which you can watch at the following link: https://www.youtube.com/watch?v=6ajqD0hoOMw

A key problem identified from early experimentation was the erosion / vaporization of electrode material from arcing and electron beam impingement. Erosion products entered the plasma and affected plasma quality and performance, prompting the following improvements.

- Monolithic tungsten electrodes to eliminate arcing
- Pre-ionizing to reduce “runaway” electrons
- Implemented a “bake-out” process and applied nitride coatings to minimize oxide formation
- Used a longer vacuum chamber with deuterium – nitrogen mix to minimize dust from electron beam erosion

Performance of the FF-2 machine improved. However, continuing issues with impurities in the plasma during further experiments led to a decision to change from tungsten to beryllium electrodes. The resulting FF-2B (beryllium) machine assembly started in 2018 and experiments started in 2019.

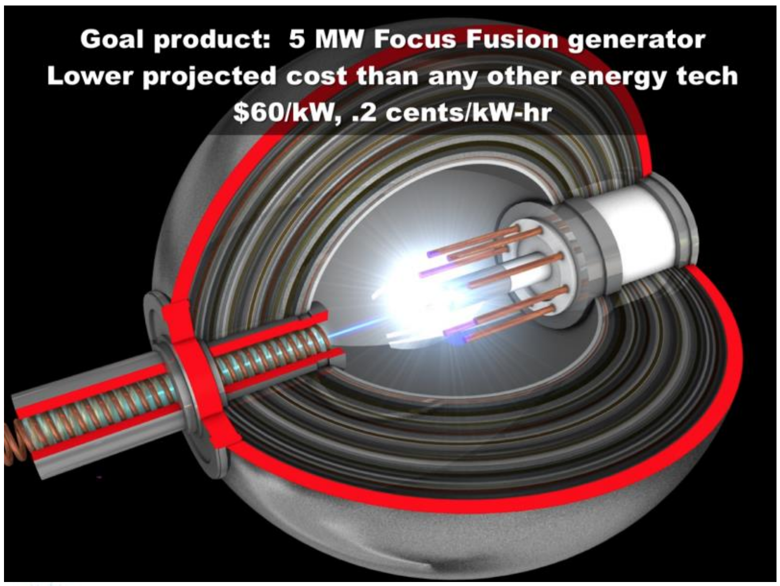


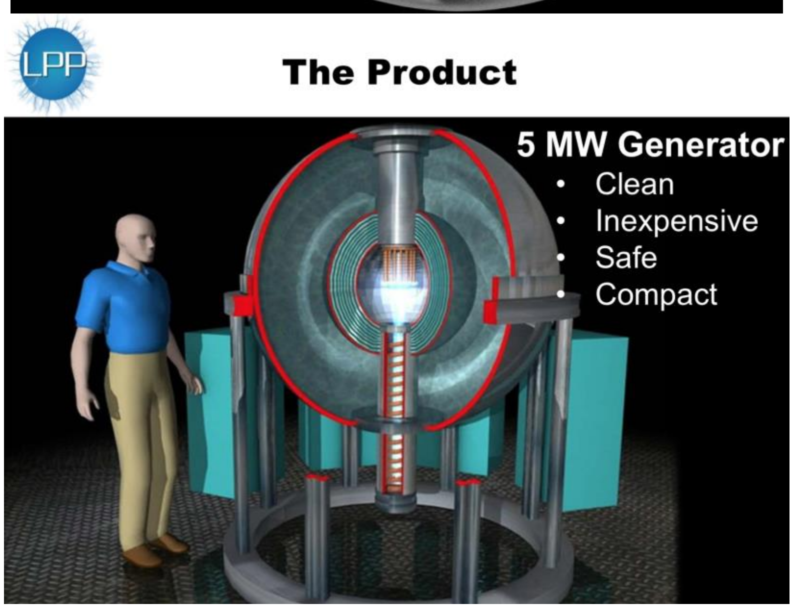
Beryllium electrodes (left) and new vacuum chamber (right). Source: LPP (2018)

In July 2019, LPP Fusion reported, “Within the overall pattern of rising yield, there have been as many as seven shots in a row with consistency in yield to within 10%.” Based on experimental results, a new anode design reported in December 2020 is expected to help LPP Fusion continue its trend of improving the performance of the FF-2B machine in 2021.

LPP vision for a commercial power plant

LPP's power plant concept is the small 5 MWe aneutronic p-B11 Focus Fusion generator shown in the following diagrams. About 2/3 of the fusion energy is released as an ion beam that can produce electricity in an advanced transformer. The remaining 1/3 of the fusion energy is released as X-rays that can be captured in a multi-layer photoelectric device. The small power plant is designed for mass production and widespread applications as single units or aggregated into a larger power plant with multiple units.





Source, both graphics: LPP Fusion

Funding

LPP Fusion's initial funding round in 2008 raised $1.2 million from the Abell Foundation and the crowd-funding service Wefunder. Between 2011 and 2020, LLP Fusion raised an additional $2.71 million through Wefunder. So far, LPP Fusion has not received any funding from DOE-FES or ARPA-E.

For more information

- E. Lerner, et al., "Fusion reactions from >150keV ions in a dense plasma focus plasmoid," Physics of Plasmas, 19, 032704, 2012: https://pdfs.semanticscholar.org/aeb8/0f5b2ec27f4f392203186513ef7c356816cc.pdf?_ga=2.240332931.1679131406.1611937698-123143870.1611937698
- "Focus Fusion: Transformative Energy Technology," LPP, 2012: http://www.agrion.org/upload/fichier/Focus%20Fusion/LPP%20Presentation-May2012-public.pdf
- "LPP Focus Fusion Report," September 8, 2014: https://us8.campaign-archive.com/?u=87935f5eb37481cdcd48cf498&id=fb0703954b
- "ARPA-E to Allow Grant Applications for Aneutronic Fusion Projects (LPPFusion)" E-Cat World, 30 October 2014: https://e-catworld.com/2014/10/30/arpa-e-to-allow-grant-applications-for-aneutronic-fusion-projects-lppfusion/
- Mark Anderson, "Startup: LPPFusion Embraces Instability," IEEE Spectrum, 22 September 2017: https://spectrum.ieee.org/energy/nuclear/startup-lppfusion-embraces-instability
- "Assembly begins on Beryllium Electrode Experiment," LPP Fusion, 24 October 2018: https://lppfusion.com/assembly-begins-for-beryllium-electrode-experiments/
- "Beryllium Experiments Begin With FF-2B: Impurities Low, Tield Rising," LPP Fusion, 3 July 2019: https://lppfusion.com/beryllium-experiments-begin-with-ff-2b-impurities-low-yield-rising/

- "Design Complete, Anode Ordered," LPP Fusion, 22 December 2020: https://lppfusion.com/design-complete-anode-is-ordered/

Patent

- US7482607B2, "Method and apparatus for producing x-rays, ion beams and nuclear fusion energy," filed 28 February 2006, granted 27 January 2009, assigned to Lawrenceville Plasma Physics, Inc.: https://patents.google.com/patent/US7482607B2/en?oq=US7482607

Videos

- "Focus Fusion: The Fastest Route to Cheap, Clean Energy," (1:04:05), Google Talks, 22 August 2012: https://www.youtube.com/watch?v=yhKB-VxJWpg
- "Why is Focus Fusion Moving Faster than Much Bigger Fusion Research Projects?" (3:00 minutes), LPP Fusion. 5 November 2017: https://www.youtube.com/watch?v=wkeFf0NflwA
- "The New Fusion Race - Part 1 – The Old Fusion Race?" (24:20 minutes), LPP Fusion, October 2016: https://www.youtube.com/watch?v=AcXYPvVxtCY
- "The New Fusion Race - Part 2 – Aneutronic Fusion?" (9:34 minutes), LPP Fusion, October 2016: https://www.youtube.com/watch?v=Je43p4jtumc
- "The New Fusion Race - Part 3 - Focus Fusion: How Does It Work?" (9:26 minutes), LPP Fusion, October 2016: https://www.youtube.com/watch?v=e4WJdkHmq64
- "The New Fusion Race - Part 4 – Fusion Race: Who is Ahead?" (7:48 minutes), LPP Fusion, October 2016: https://www.youtube.com/watch?v=QvYmchl4ZGM
- "The New Fusion Race - Part 5 - Focus Fusion Next Steps" (15:27 minutes), LPP Fusion, October 2016: https://www.youtube.com/watch?v=nIifHGu7JA4
- "The New Fusion Race - Part 6 – Fusion Race Stats - 2017" (4:08 minutes), LPP Fusion, 2017: https://www.youtube.com/watch?v=yujkXJV4kZ0