LPPFusion Report
July 1, 2021

Summary:

- **Fusion Experts Urge "Much Higher Funding" for LPPFusion**
- **Anode Installed, Switch Assembly and Testing Advance**
- **Major IT Upgrades Accomplished**

Fusion Experts Urge "Much Higher Funding" for LPPFusion

"The attractiveness of a low power, low capital cost, and a 'clean' fusion power reactor system is worthy of continuing the research at a much higher funding level."

That is the key recommendation of an "Evaluation of LPPFusion Dense Plasma Focus Research", a **new report by a committee of leading fusion technology experts**. The committee, chaired by Dr. Robert L. Hirsch, former director of fusion research for the United States government's Atomic Energy Commission and Energy Research and Development Administration, concluded that "LPPFusion has made an impressive effort to address DPF physics and engineering issues given the limited number of personnel involved," but that the "program is vastly underfunded and merits a much higher funding level."

The evaluation was requested by LPPFusion's largest investor, The Abell Foundation, and Abell invested the funds to pay for the committee members' time. LPPFusion asked Dr. Hirsch to assemble the committee and to chair it. The report was based on a day-long meeting on June 14 via Zoom with LPPF Chief Scientist Eric Lerner and Research Scientist Syed Hassan, as well as on extensive preceding written questions and answers from the committee members, and on their reading of LPPFusion peer-reviewed journal articles. In addition to Dr. Hirsch, the committee members were Dr. Gerald L. Kulcinski, former Director of the Fusion Technology Institute, University of Wisconsin-Madison; Prof. Dennis Papadopoulos, Co-Director, East-West Space Science Center, University of Maryland, College Park; and Dr. John Santarius, Associate Director for Alternate Applications and Concepts of the Fusion Technology Institute.

The committee's report noted the advantages of LPPFusion's basic approach, using the dense plasma focus device with hydrogen boron (pB11) fuel: **"Pursuit of the p11B fusion fuel cycle is highly desirable, because that cycle does not directly emit neutrons, which greatly complicate concepts based on other fusion fuel cycles. … In principle the DPF has a number of attractive aspects as a fusion reactor. Included are relative simplicity and small size."** The committee also pointed to the Quantum Magnetic Field (QMF) effect as **"an attractive and innovative aspect of the DPF aneutronic fusion"** approach. The QMF effect, which is important only at the high magnetic fields that the DPF can achieve, reduces cooling of the fusion plasma by X-ray emission, allowing much faster fusion burn and higher fusion energy production.

Dr. Hirsch and two of the other committee members had taken part in a 2013 evaluation of LPPFusion's work and in the new report the committee recognized important achievements since that review. Two involved records for fusion research: **"LPPFusion has increased the confined mean ion energy from 150 keV to over 250 keV. This is currently the highest confined ion energy of any fusion device."** the report stated. In addition, **"Using beryllium electrodes, LPPFusion achieved the highest purity plasma reported in any fusion experiment."**

At the same time, the report objectively pointed out the significant challenges that still lie ahead for LPPFusion's R&D effort. Despite the simplicity of the dense plasma focus design, "The physics of the DPF is extremely complicated. While LPPFusion has done an admirable, first-cut analysis of the related physics, much remains to be done to develop a good understanding of the physics and to advance to the point where the physics understanding is fully capable of being a useful predictable vehicle." Of course, LPPFusion is not alone here, the report goes on: "However, no other fusion concept can be said to be completely understood either." In addition, "the margins for error in each aspect of the DPF are relatively small." That is, we really need to hit the bull's eye!

To meet these and other challenges, the committee emphasizes the need for "greatly expanded funding". This would enable LPPFusion to simultaneously fund several experimental DPF devices, in addition to FF-2B, and to make significant improvements in diagnostics—the instruments we use to study the fusion plasmas. The discussions with committee members led to some specific suggestions for new instruments, which we'll be detailing in future reports.

The full evaluation is available here, with additional biographical information on committee members. LPPFusion hopes that the circulation of the report will help lead to making its recommendations into reality.

Anode Installed, Switch Assembly and Testing Advance

The LPPFusion research team has been extremely busy preparing for our next experiments—too busy in fact to put out this report until now. (If you want more frequent updates, please follow us on Wefunder and Facebook.) Our first big milestone was installing our new anode. The assembly day was May 4th. It went well—the 4th was with us! LPPFusion Research Scientist Syed Hassan, assisted by Chief Scientist Eric Lerner, removed the temporary anode plate from the top of our fusion device and then carefully replaced it with the new anode, assembled onto its own steel plate.

Our first step, inside the glove box, was to **merge the anode stalk and anode base** (already attached to the outer steel plate.) We **achieved the low electrical resistance** (micro-ohms) planned. Syed then put a custom flange on top of the anode to connect it to the upper vacuum chamber. The anode has a hole in its center to allow the escape of the electron beam, which dumps its energy into the upper vacuum chamber.

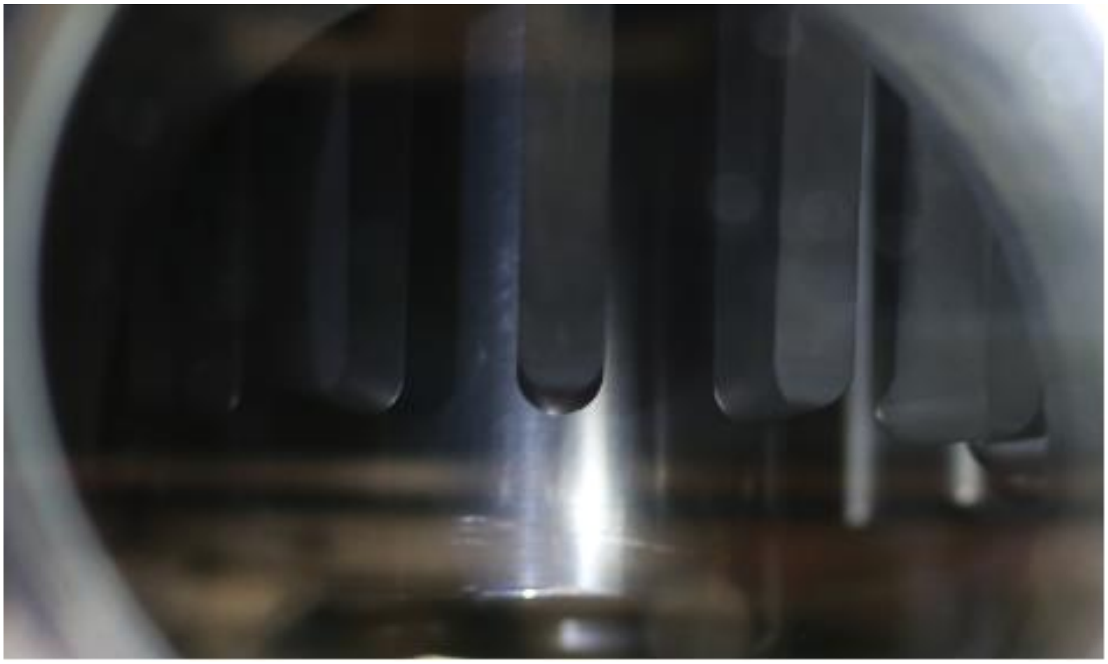

Fig. 1 The new anode in FF-2B. It is shown here through the front chamber window (the anode is the central shiny cylinder, surrounded by the cathode vanes).

Syed then put threaded rods into the temporary steel plate and with lab jacks carefully lifted it vertically, making sure that it did not hit the ceramic insulator, still inside our device. All this time we continued pumping out the vacuum chamber, so no beryllium dust (if any is still present) could escape outwards. Once a new rubber-sealed cap was put on top, we started to prepare for inserting the new anode. The anode had to be centered on the insulator to within a tenth of a mm, 1/250 of an inch, so careful planning was required.

We attached the **anode assembly** to a steel rod with threaded bolts and then carried it into the experimental room. Once it was aligned with other threaded rods on the machine, Syed carefully lowered the anode inside the insulator, keeping watch on two levels to keep the anode vertical, while Eric monitored from a cross-wide viewpoint. The operation, completed at 10 PM, was a complete success, with **good centering**.

The next two weeks in May were devoted to a **bake-out of the vacuum chamber and the vacuum system**. We raised the temperature with external heating coils to a gentle 120 ℃ to get rid of moisture that clings to metal parts. This brought the vacuum in the system down to only 5 microtorr, only 7 billionths of atmospheric pressure. Good vacuum is needed to exclude oxygen from the chamber when we fire. This will prevent the formation of oxides on our electrodes and **reduce erosion**.

During this period, we also performed a preliminary **test of the new smaller switches**. We exposed them to a high voltage from our power supply to see if there would be any flashover arcing in air. It looked like the switches passed the test.

The rest of May and early June, we concentrated on **assembling the new switches onto the FF-2B device**. With 16 switches, we had a lot to do, so at times LPPFusion Chief Information Officer Ivy Karamitsos and Systems Administrator Jose Varela pitched in as well. Syed also was busy preparing four new trigger cables to attach to the switches. The cables carry the trigger electrical pulse from the main trigger generator to each switch. Since we only had 12 of the large switches (and were using only 8 of them in our last experiments) we needed four more cables. Attaching them correctly was tricky, as they needed to hold a 30kV charge when the trigger system is turned on. We then successfully tested the entire trigger system, which sends a sharp 60kV spark to the switches when we fire it.

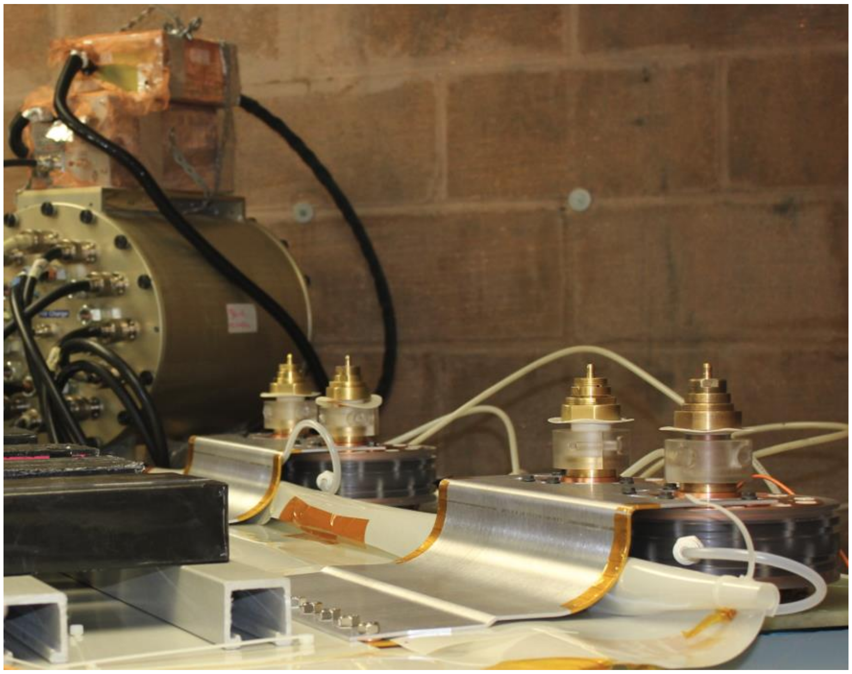

Fig. 2 The new dual switches during assembly of the switching system. The switches are the dark plastic cylinders, topped by the brass spark plugs. At this stage of assembly, they are not yet attached to the trigger system. The main trigger generator is the large brass cylinder to the left, with the trigger cables snaking out of it.

On June 10, we took the next step and tested the whole switch and trigger system by applying a charge to the capacitor bank. We wanted to make sure there were no flashovers sparks before we made final preparations for a real shot, where we fire the capacitors, allowing huge currents to flow across our electrodes. Unfortunately, we did get **a small flashover spark from one switch**, right before we got to the full 40kV charge.

In retrospect, our preliminary test of just two switches was graded a bit too easy. We passed our first effort at insulating the switches against flashover sparks because we did not hear the “snap” of a large flashover spark. But we had heard a “sizzle” sound which, we realized later, was really a series of small flashovers. After another two weeks of experimenting with different ways of insulating the switches—mainly with Kapton tape—our work seems to have passed **the “sizzle” test**. **The two test switches were quiet all the way up to 43 kV**. More assembly and testing still lie ahead before we are ready to fire, hopefully soon.

Major IT Upgrades Accomplished

LPPFusion’s IT team, CIO Ivy Karamitsos and Systems Administrator Jose Varela, have completed a major upgrade of the IT network and hardware. The upgrade replaced equipment dating back to 2013-2014. By the beginning of this year, network speeds and data access had become a problem. So, the IT team carried out major upgrades over the last six months. Planning had been underway since last year, but like many others, we faced delays due to pandemic-related supply-chain constraints. Our new network equipment was finally deployed in May. With our updated equipment at both the lab and the home office we are now able to:

- Create **backups** by making full system images incrementally. This avoids having to re-install programs in the event of drive crashes. Deduplication is automatically performed before the images are encrypted and securely copied to a remote location, reducing storage cost.
- **Swiftly synchronize data** as it becomes available between **lab server and home office server.** This vastly improves availability of data and internal data sharing.

- **Synchronize data from client to server**

These steps have vastly improved our ability to quickly and effectively work together regardless of location. We are continuing to synchronize needed data to each client, as well as to implement the latest security standards.

While this hardware upgrade was going on, the IT team also **updated the website** with a new theme, new plugins and a new server operating system. This resulted in minor changes to appearances, but big changes in functionality including easier maintenance and improved social media sharing. Finally, the team **redesigned and rewired our combined home office and video recording studio.** This involved solving some tough lighting and audio quality problems, but it has given us two different sets in the same room, allowing us to record both day and night. If you watched our two new 2021 videos, we think you'll notice their improved quality.

Fig. 3 Behind the scenes at LPPFusion Studios. Our LPPFusion home office's main room (top) serves as a work area for Chief Scientist Eric Lerner (responsible for messy papers); as a daytime video set (bottom left, with server station at far left) and as a nighttime video set (bottom right—excluding messy papers.)