Report December 28, 2023

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Wefunder 2023, Reg D. Campaigns End, $700,000 Raised

Our LPPFusion 2023 fundraising campaigns through Wefunder and our Regulation D offerings wound up with a big boost in December. Thanks to $130,000 in Wefunder investments and $137,000 in direct Reg. D investments in the first half of December, including a $100,000 investment from a long-time investor, we wound up with a total of $478,000 from Wefunder's crowdfunding platform and $229,000 from Reg D. accredited investors. Deducting Wefunder's 6% fee, this gave us a net investment for the year of $678,000. Many thanks to all who have invested!

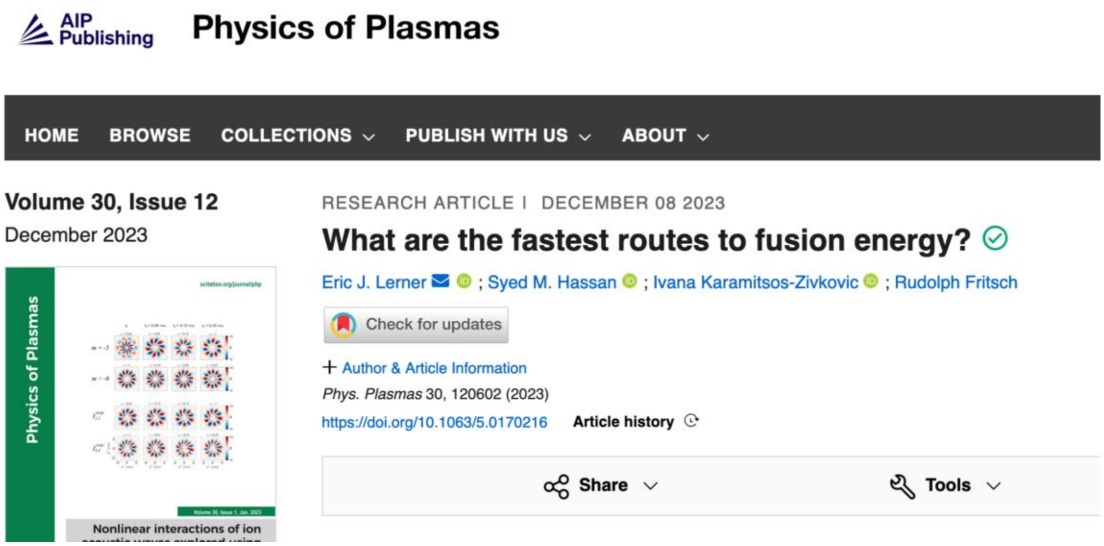
This year's campaign was a big step up from 2022, with our Wefunder raise increasing by 50%, a lot more than the crowdfunding industry's overall increase of 14%. The total also exceeds our minimum goal of $600,000 to maintain our operations.

However, it fell far short of our ultimate goal of $2 million in a single year. That's what we need to have money in the bank and enough ongoing funding to increase our full-time staff to five, hiring another vital researcher for the lab and another full-time person for all LPPFusion's other work, including fundraising. That would double our rate of progress towards our goal of net energy, and then to commercialize fusion in this decade.

In the coming year, we'll be working on new ideas to make the leap to $2 million in a year. We welcome your help and suggestions.

LPPFusion's Peer-Reviewed Paper Shows Fastest Routes to Fusion

The leading technical journal *Physics of Plasmas* on Dec. 8 published online LPPFusion's roadmap to the "Fastest Routes to Fusion Energy". In this peer-reviewed paper, the LPPFusion team shows that "the approaches that combine hydrogen-boron (pB11) fuel with high-density plasma have an easier, less resource-intensive path" to economically practical fusion energy. **This fastest route of course includes LPPFusion's own approach using pB11 fuel and the dense plasma focus device.**



While LPPFusion has long explained the advantages of the fast route to fusion, this paper is the first time this perspective has been laid out in a peer-reviewed journal, giving it more technical credibility. The paper is part of a Special Collection in *Physics of Plasmas* on "Private Fusion Research: Opportunities and Challenges in Plasma Science", which include perspectives from other leading fusion companies. The papers were mainly reviewed by researchers at other private fusion companies. Inclusion in the Collection gives LPPFusion's new paper greater prominence in the journal and wider readership.

The paper, authored by LPPFusion's research team of Eric J. Lerner, Dr. Syed M. Hassan, Ivana Karamitsos-Zivkovic and Rudolph Fritsch, demonstrates in detail the basic advantages of the approaches that use both dense plasma and pB11 fuel. Only these approaches have any feasible path to capital costs less than those of existing energy sources and thus to a reduced overall cost of a transition away from fossil fuels. This is because only dense plasma approaches with aneutronic fuel can achieve compact generators with direct energy conversion.

All generators using deuterium-tritium fuel have to use expensive thermal conversion systems, like steam turbines and generators, to convert heat energy to electricity and all have to be large to minimize damage from the neutrons this fuel produces. Only pB11 fusion generators , using a fuel that produces no neutrons from the main reaction, can avoid these costs by directly converting the energy of moving charged particles to electricity in a circuit, without thermal conversion. In addition, only dense plasma approaches can achieve the energy density needed for compact, and thus cheap, generators.

As a result, the paper points out, right now the companies using dense PB11 approaches are the leaders in actual results, and far away lead in getting results for less money. The two leaders, LPPFusion and HB11, have spent only millions, not billions of dollars, yet have the best "wall-plug efficiency"—the ratio of fusion energy out of the device to energy in. (At the moment, LPPFusion's results lead HB11 by about a factor of 100.)

Yet, the paper concludes, "the dense-plasma, pB11 approaches have received a wholly insignificant fraction of governmental funding and less than 1% of total private funding."

Filaments Line Up, but Anode Cracks, Delaying Boron

As we prepare for our hydrogen-boron tests, we've made progress in ending an obstacle to higher fusion yield--the disruption of our plasma filaments. The filaments—dense threads of electric current, magnetic fields and plasma (current-carrying gas)—are the first step in increasing the density and temperature in our FF-2B experimental fusion device. Fusion requires both high density and temperature. For a long time, we'd been fighting the problem that the filaments formed at the beginning of our microseconds-long pulse, got disrupted before they are compressed into the dense plasmoid, where the fusion reactions take place. Disrupted or disorganized filaments lead to less symmetric compression, less density in the plasmoid and thus less fusion.

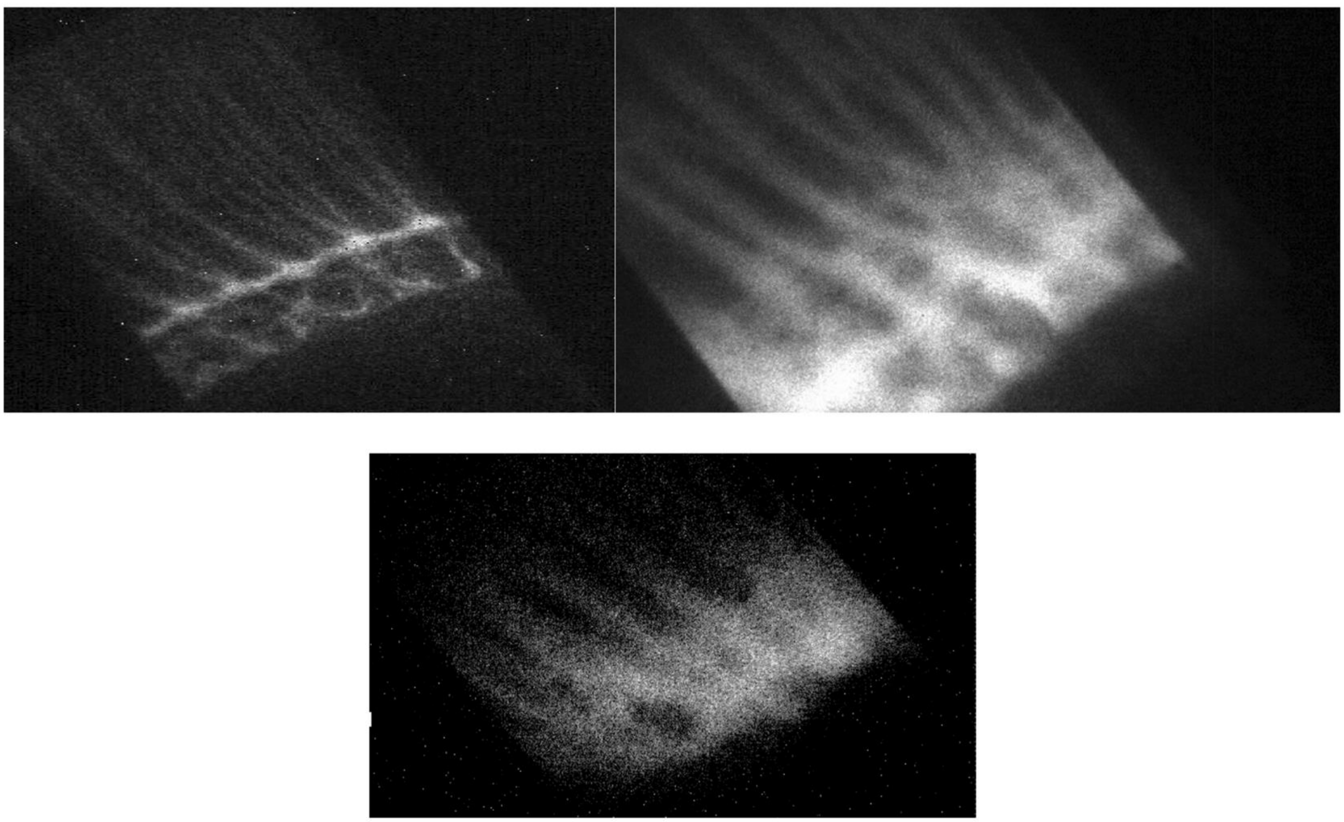


Image of filaments from our experiments in 2019(upper left), May of this year (Upper right), and October of this year(bottom) show decrease in disruption.

We saw this process in our images of the filaments back in 2019 (top left image). In this image, taken with our ultra-fast ICCD camera, the plasma is moving down the inner electrode (the anode) which here is down and to the right. In the rear part of the sheath (to the left) the filaments , the bright vertical threads, are neatly arranged almost in parallel. But in front of the bright horizontal line, the filaments are a mess—disrupted into a tangle. It was this part of the sheath, unfortunately, that was compressed into the plasmoid.

We figured out that a big part of the problem was a relatively slow rise in current in the very first nanoseconds (billionths of a second) of the pulse. Too low current did not create the strong magnetic fields needed to produce the neat, organized filaments. We thought that our new switches, installed this spring, would speed the initial turn-on.

In May, we got the switches working and they did indeed speed up the turn-on. But the filament disruption was not substantially improved (image at upper right from May 4, 2023).

We identified some key problems in our initial conditions and fixed them, leading to our higher current and fusion yield reported in October of this year. Our recent analysis of the ICCD images (lower image from October 20, 2023) shows that we have indeed made big progress in preventing the filament disruption. In this image, we can see that the filaments remain nearly parallel to each other right up to the front of the sheath, where it counts. The horizontal line of disruption has essentially disappeared. This was a big factor in increasing density and fusion yield.

But we still have a way to go. A glance at the image shows that the filaments this year are a lot fatter than those in 2019. That is not good, because the thinner the filaments, the smaller and denser the plasmoid that they twist into. So fat filaments limit fusion yield. We have some good ideas on how to fix this as soon as we get back to firing shots, such as fine-tuning the gas mix to speed the breakdown further.

Unfortunately, that will not be for a month or so, as we discovered that our anode had cracked and has to be replaced. We saw that a large leak occurred after our shot on Nov.20, but we could not identify the source of the leak for some time. With the help of some new equipment, we finally tracked it down and found that the source was a major crack in the anode, which had broken the vacuum seal at the top of the anode.

Fortunately, the crack clearly comes from a different source than the last one, back in 2020. The crack's starting point far from the tip makes clear that it was due to stresses created by the electron beam that goes down the central hole in the anode, while in 2020 the crack came from the filaments of current at the tip. We think we can easily eliminate this failure mode in new anodes and we will be ordering two new ones—to have a spare—in early January. This anode lasted three hundred shots compared with only one hundred for the first one, and we feel confident the next ones will last well over a thousand shots.

We don't expect to get the new anodes before March. However, in the meantime we are going to do some shots with our old tungsten electrodes. While they produce a lot more impurities than the beryllium ones, we think some quick tests will give us data that will speed our work once we get the beryllium anodes back.

During December, LPPFusion's Hassan completed the upgrades in the FF-2B device needed to use hydrogen-boron fuel. He completed and successfully tested a new heating system, required to keep the decaborane compound in a gaseous state. In addition, he completed the new fuel-handling system needed to feed the fuel into our vacuum chamber in a controlled way.

So, once we complete the tests with the new beryllium anode and get the conditions needed to run with the boron fuel, our machine will be ready for that fuel. The cracked anode does mean a delay in getting to hydrogen-boron, but not a long one.

International Business Times, Asia Times Cover LPPFusion

In a Nov.20 article in the widely-read International Business Times, Joe James writes "the small fusion company that has gotten closest to getting more energy out of the device than is put into it is LPPFusion, in the U.S. They have spent millions, not billions, of dollars to achieve this progress. They are using devices that are far smaller and cheaper than NIF or ITER. LPPFusion's FF-2B device weighs 3 tons, far smaller than ITER's 400,000 tons.”

This is the first time in 2023 that a mass-circulation media outlet has recognized what we’ve reported in peer-reviewed journals: right now, LPPFusion is the leader in getting scientific results leading to cheap, clean, safe, unlimited and decentralized fusion energy.

We got more mass media coverage on December 3, when Asia Times published the first of a three-part series by LPPFusion’s Lerner on “The Big Bang never happened – so what did? Cosmic evolution without mythology”. In this series, Lerner explains how the evolution of the universe can be explained without dark matter, dark energy, inflation, cosmic expansion or the Big Bang—and why it matters in the here and now. “Perhaps most critically, “Lerner writes, “some of the key processes that explain the evolution of the cosmos can be harnessed here on Earth, specifically for the production of fusion energy – cheap, clean, safe and unlimited energy to replace fossil fuels.”

A second part, “Fusion from filaments on Earth and in the cosmos”, published Dec.11, describes how huge filaments of current, similar to but vastly larger than those in our FF-2B device, interacted with gravitation to form the hierarchy of stars, galaxies cluster and superclusters of galaxies we now see in the cosmos. A third part, to be published in January, will describe the present phase of cosmic evolution, dominated by the fusion energy we intend to capture here.

LPPFusion Joins International Collaboration on Proton-Boron Fusion

This month, LPPFusion officially joined the PROBONO international research collaboration, which brings together researchers working toward proton-boron (pB11) fusion, also called hydrogen-boron fusion. PROBONO is funded by the European Union and was initially limited to laser-based fusion, but has now expanded to include all approaches using hydrogen-boron fuel. Unfortunately, the name, which is legal jargon for “for free”, is apt as the amount of the funding is at the moment very small and is limited to travel and administrative costs, not research.

However, the existence of the organization just as an official network will make setting up collaborations among pB11 fusion researchers much easier. We at LPPFusion have joined both the experimental and simulation working groups and expect to be starting concrete collaborations in the coming months. Such collaborations can substantially speed up the advance toward fusion with this ideal fuel, which produces no nuclear waste and allows cheap direct conversion to electricity.