LPPFusion Report
November 7, 2019

Summary:

- **Oscillations Down, Fusion Yield Up**
- **Plasma Focus Researchers Agree on Key Point**
- **Congress, NJ Legislature Consider Money for Private Fusion**
- **Nov. 13 Fusion Event in Brooklyn**
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Oscillations Down, Fusion Yield Up

LPPFusion's efforts to reduce troublesome oscillations in our FF-2B experimental fusion device have started to make progress. On October 21, we cut the highest-frequency oscillations in half, and increased fusion yield by 30% over our best previous shot with FF-2B. This puts fusion energy yield at 1/8 joule (one joule is one watt-second).

Is 1/8 joule a lot or a little? Compared to other private fusion efforts, it's a lot. Other than LPPFusion, TAE Technologies is the only fusion company that has reported any fusion yield at all, and in March of this year they published a yield of 40 microjoules, which is 3,000 times less than our Oct. 21 shot. They have not published the energy input of their machine, but it is definitely more than FF-2B's.

Our Oct. 21 shot is also pretty good in terms of LPPFusion's recent work. It quadrupled the yield we got at the same conditions before we had reduced the oscillations (the highest previous yield had been at different conditions). It ended a 70-shot drought of new fusion yield increases. It also surpassed, by a bit (6%), any fusion yield that we achieved in 2017-2018 using tungsten electrodes.

Figure 1 gives an idea of the progress made. These graphs show the rate of change of the current in the device in shot 1 of August 9 and shot 1 of Oct 21. The early oscillations on Oct 21 are slower, and they damp down much faster than on Aug. 9. The pinch—the big dip in current—is much bigger on Oct 21. This shows energy moving much more quickly into the plasmoid where the fusion takes place, indicating a smaller, denser plasmoid. That is what produced four times as much fusion energy as on Aug. 9.

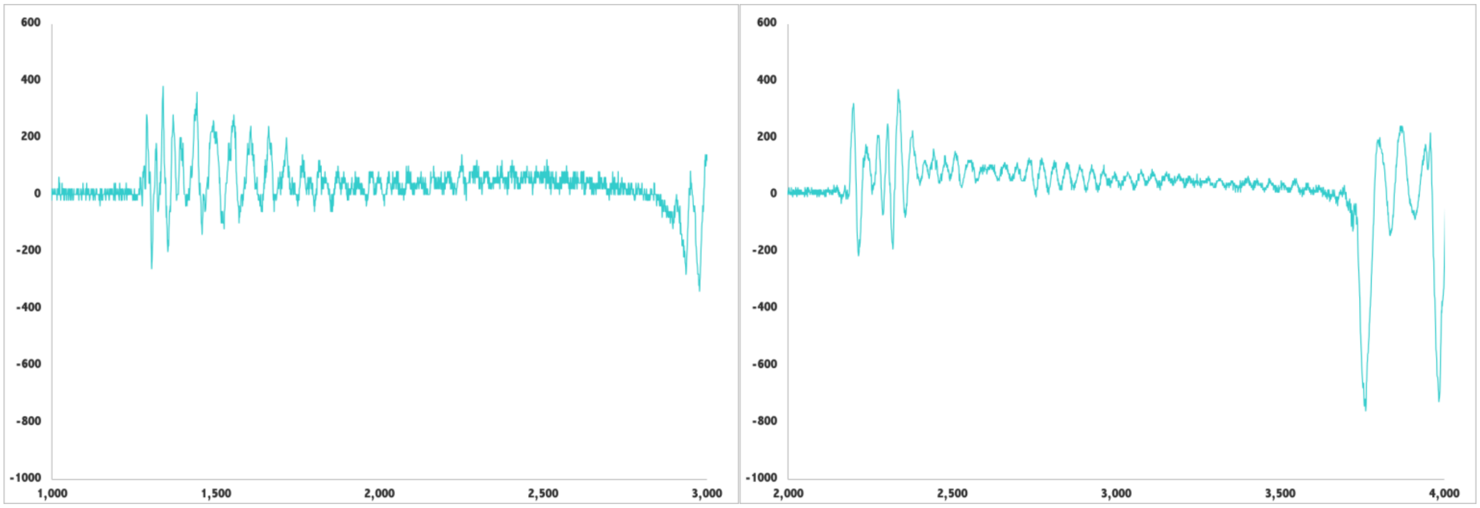

Fig. 1 August 9, shot 1 (left) shows the high frequency oscillations in the current at the start of the shot and the subsequent small dip at the pinch, when the fusion reactions take place. After we adjusted the switches, in October 21, shot 1, (right) the initial oscillations decreased in frequency and damped out quicker, leading to a much deeper current dip at the pinch and four times as much fusion energy. Vertical axis measures the rate of change of the current in units of 10 A/ns and the horizontal axis measures time in ns.

But 1/8 J is little compared to our near-term goals. To get a new record for our project we have to exceed the ¼ J that we achieved with FF-1 in 2016, using longer electrodes. To get closer to net energy (more energy out of the device than we put in) than any other fusion project in the world, we need to exceed 0.4 J. Beyond this, to fully validate our theories of how the plasma focus device works, we need to get to 10 J fusion yield. So we still have a ways to go, but our new understanding of the oscillations will help to get us there fairly quickly.

We knew back in September that the oscillations were caused by something in the external circuit of our machine, not inside the vacuum chamber (see Sept. 12 report). We found that the circuit was oscillating at four frequencies: 16 MHz, 28 MHz, 38 MHz and 40 MHz. Like detectives eliminating suspects, we started to rule out sources by disassembling the circuit and seeing when each frequency disappeared. LPPFusion Chief Scientist Eric Lerner and Research Scientist Syed Hassan could test the circuit safely by firing the trigger pulses. This pulse, which triggers the capacitors when they are charged, is too small to do any damage, but is big enough to set off the oscillations.

As we had previously thought, the lowest frequency, 16 MHz, was caused by current sloshing back and forth along the aluminum plates that connect the switches to the electrodes. That was not our main worry, as that frequency had always been present. The 28 MHz frequency came from the "ringing" of the trigger cables that carry the trigger pulse to the switches. The 38 MHz oscillation was definitely coming from the switches themselves.

That left the 40 MHz "tone" as the mystery. On the suggestion of LPPFusion's Electrical Engineer Fred Van Roessel we checked out the grounding of the bottom aluminum plates, which were attached to a ground plate on the floor. Fred suggested that only one connection should be between the two plates. They were separated by just the right distance to explain the 40 MHz signal. Indeed, when two of three grounds were removed, the 40 MHz dropped a lot.

So the switches were the culprits—their 38 MHz oscillations started the ringing at other frequencies. But what caused the switches to start oscillating? (The "motivation" for the crime.) The fact that the current in the switches was oscillating even when the capacitors were not charged was a big clue. When the capacitors are not charged, the high voltage (*minus* 50 kV) pulse from the trigger causes a spark to jump to the nearest ground—which is the top plate that the spark plug is attached to, separated by a Lexan insulator. But when the capacitors are charged, the additional electric field created by the charge of *plus* 40kV causes the spark to jump vertically, allowing current to flow out of the capacitor to the top plate.

This is what is supposed to happen. What instead was happening in our case was that the switches were breaking down horizontally, to the top plate first, even when the capacitors were charged. That caused the back and forth motion of the plasma formed within the switch. That sloshing plasma in turn caused the current oscillations.

Why did the oscillation get worse in 2019? It looks like it was because the switches were firing so close to simultaneously, making all the switches oscillate in unison. Before this year, the switches fired at different times within a 20-ns window, enough to smear out a 26-ns-long oscillation. But with the new ceramic inserts, the switches became sufficiently similar to fire within 4 ns, putting all the oscillations in sync, making them larger.

The solution is to adjust the spark plugs, which are mounted on screw-threads, to move closer to the capacitors, reducing the vertical gap and leading to the switches firing first vertically. This is tricky since we must also increase the pressure in the switches to prevent them from firing by themselves, before the trigger. It will take us a bit to get the adjustment right, but we have already seen the initial results. After initial adjustments, we saw the partial reduction in the oscillations and a rise in fusion yield. We expect that the complete elimination of the oscillations will result in more dramatic increases in yield.

Plasma Focus Researchers Agree on Key Point

At a workshop in Warsaw, Poland, plasma focus researchers from around the world agreed on a key aspect of the functioning of the plasma focus device and clarified what we still disagree about. The key point we unanimously agreed on is that in plasma focus devices with large currents, the fusion reactions are caused by hot ions that are confined and orbiting repeatedly in a limited space. This is a very important conclusion, since critics have for decades insisted that the plasma focus produces neutrons by a “beam-target” process, in which the ion beam hits the background plasma (or a dense blob) and passes through once. If this were the real mechanism, it would never be possible for such devices to produce net energy. That requires confined hot ions, colliding with each other repeatedly until they undergo fusion. So, the unanimous scientific conclusion of dozens of researchers with, collectively, centuries of experience with the device is a strong refutation of this criticism.

The workshop was a special meeting held Oct 4-5, of the International Scientific Committee of the International Center for Dense Magnetized Plasma (ICDMP). The Committee serves as a coordinating network for plasma focus researchers around the world. Committee Chair Dr. Sunil Auluck initiated a process in 2018 of determining what researchers agree on about the plasma focus and what we don’t. In the 20th century, there were indeed sharp disagreements about how the device worked and these disagreements were one factor hindering the funding of plasma focus research. Funders argued that the plasma focus could not be considered a serious contender for fusion energy production if no one knew how the fusion reactions took place. As the oldest generation of researchers passed from the scene, much of the disagreement ebbed, leading to major areas of consensus in the last 15 years. Dr. Auluck’s proposal, enthusiastically accepted by the Committee was to set up a formal process to determine just what that consensus was.

The discussion, initially via the internet, took a big step forward with the in-person meeting, which LPPFusion’s Lerner actively participated in. After word-by-word negotiation and polishing, the final formulation of consensus was adopted unanimously, and was also endorsed via internet by Committee members not attending the meeting. A full report will be posted in the near future on the ICDMP website.

In our next LPPFusion report, we’ll discuss some of the disagreements remaining and our efforts to resolve them experimentally.

Congress, NJ Legislature Consider Money for Private Fusion

Thanks to the effort of the Fusion Industry Association and its director Andrew Holland, the US Congress is now considering a bill to aid private fusion efforts. The House version of the Energy and Water Appropriations bill only has $4 million for this important initiative, while the Senate version has $20 million. Please contact your Congressman to support the Senate version. Those on the House Appropriations committee are the most important to e-mail, but your own Congressperson will help; too. Here's the list of the key members:

> Marcy Kaptur (D-OH) ,Pete Visclosky (D-IN), Debbie Wasserman Schultz (D-FL), Ann Kirkpatrick (D-AZ), Derek Kilmer (D-WA), Mark Pocan (D-WI), Lois Frankel (D-FL), Mike Simpson (R-ID), Ken Calvert (R-CA)Chuck Fleischmann (R-TN), Dan Newhouse (R-WA)

As noted in the last LPPFusion report, the NJ legislature is also considering a fusion funding bill. The decisions for this session will be made in November and December. So we again urge everyone to please send e-mails to Sen. Pennachio at SenPennacchio@njleg.org expressing support for these bills. Of course, if you live in NJ, or especially in the 26th Legislative district, mention that.

LPPFusion in Brooklyn Nov. 13

LPPFusion President and Chief Scientist will be giving the first in-person public update on FF-2B's progress at the Soapbox Gallery in Brooklyn, NY (636 Dean St.) at 7:30 PM on Wednesday, Nov. 13. The presentation will follow a screening of the award-winning documentary "Let There be Light" about the global fusion research effort. More details on the events page of Soapbox Gallery. If you are in the New York metropolitan area, please stop by!

Fusion Song Contest Extended to Dec. 1

We are extending our fusion song parody contest by one month. We ask that contestants send links to professional videos of the songs that they are parodying, so people get the idea of the tune. Since LPPFusion staff have submitted entries, we will be judging winners through internet voting by all of you, starting Dec. 1. So, get your entries in and await the voters' decisions!