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Lawrenceville Plasma Physics, Inc

High technology research, development and consulting in plasma physics, X-ray sources, and Focus Fusion

LPPFusion Report
February 2, 2018

Summary:

- **Wefunder Equity Crowdfunding Passes Half-Way Point**
- **Tungsten Experiments Concluding with Major Upgrades**
- **LPPFusion Publishes World Record Results**
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Note to subscribers: This report covers the last three months. We've sent out interim updates during that period. The Oct. 27, 2017 publication of our results, mentioned in our updates, is included here again for completeness.

Wefunder Equity Crowdfunding Passes Half-Way—Over $560,000 Raised

Thanks to over 260 far-sighted investors, LPPFusion's equity crowdfunding on Wefunder has now raised over $560,000, over half way to the one million dollars needed to quicken our research for safe, clean, cheap and unlimited energy! The campaign, started Nov. 9 is now approaching the three-month mark. LPPFusion expects to wind up the campaign in April.

Unlike previous share rounds, this crowdfunding round is open to all, everywhere. The minimum investment is $1,000, considerably less than the $5,000 minimum of LPPF's Regulation D offering. The shares are at the same $125 price as in the Regulation D offering. The Regulation D offering is also ongoing.

"We are offering shares both ways," explains LPPF President and Chief Scientist Eric J. Lerner. "We get the Regulation D money right now—and we always need money!—while the crowdfunding money we will only get at the end of the campaign. So, if you are not a US citizen or resident and want to invest more than $5,000, we encourage you to contact us through the "investor" tab on our website for direct investment. The same goes for US accredited investors. Everyone else we invite to invest through Wefunder.com"

The campaign has already raised well over the minimum goal of $400,000, achieved Dec. 22. So this means LPPF will certainly be getting at least the minimum money our project needs to move on to our critical experiments with beryllium electrodes. But the full million dollars is needed for us to hire another researcher, and to buy critical long-lead-time items, so that we can accelerate our research. Thanks to all who have made this possible!

Tungsten Experiments Conclude with New Insights, Upgrades in Instruments and Equipment

After some delays due to the need to replace and upgrade elderly equipment, the LPPF research team is now concluding the experiments with tungsten electrodes. While the experiments originally were planned to be completed in the fall of last year, the failure of the main roughing vacuum pump and the trigger head stopped operations for two months. However, the new upgraded equipment has allowed the team to fire shots more quickly. In addition, the improvements in our imaging capabilities have given us valuable insights into the plasma focus functioning.

The trigger head provides the spark to the main trigger switch. This switch in turn generates the spark for the 8 switches on the capacitors that allow the current to flow to the electrodes. The original trigger head had functioned for 8 years, so was due to fail. The upgraded trigger head provides a nearly three times larger spark, so provides a much more reliable triggering sequence. The roughing pump was of an old, piston pump design, and was replaced with a new scroll pump, which squeezes the air out between two rapidly rotating spiral vanes. Its greater power allows faster pump downs after each shot, so less time between shots.

With the two upgrades the LPPF team has been able to fire as many as 8 shots in a day and is close to the 25 shots per week that are planned for the upcoming experiments with beryllium electrodes. Once LPPF has the crowdfunding money in hand, we also intend to purchase spares of critical parts so that future breakdowns won't lead to long delays awaiting replacements.

Once firing resumed in January, LPPF Research Physicist Dr. Syed Hassan re-aligned the optical path to our ultra-fast ICCD camera to obtain close-ups of the plasmoids through our large quartz window. Using this new alignment, the team obtained a sequence of images that provide the clearest picture yet of the evolution of the plasma as the dense plasmoid forms. (The plasmoid is where the fusion reactions take place.) The images were taken from different shots, with the sequence determined by the difference in time between the time the image was taken and the time the first X-ray pulse was observed. The six image sequence is shown in Figure 1 and is cycled in the animation.

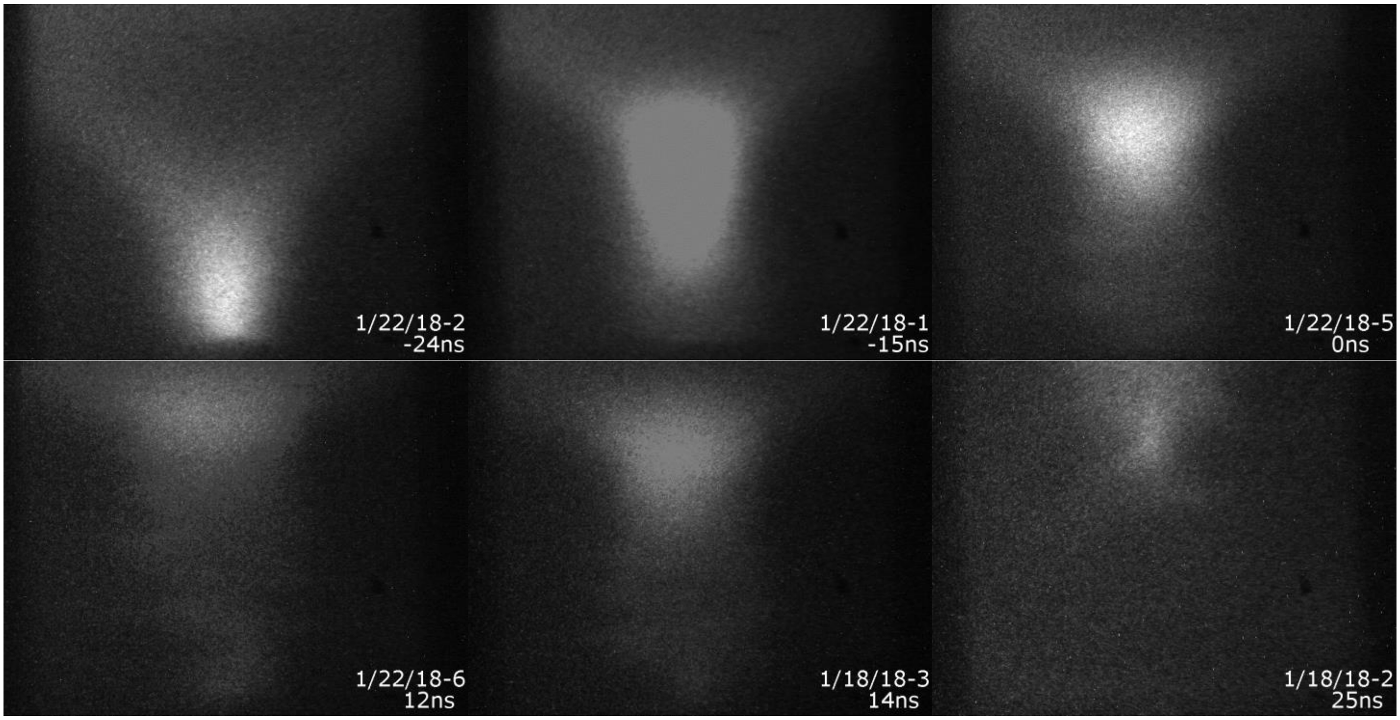

Fig. 1 Collage of 6 ICCD camera images (0.2 ns exposure time) of pinch in FF-1 device.

The first two images (-24ns and -15ns) show the pinch region, where the electric current converges, first forming then moving away from the anode. (These images are inverted for easier viewing—in the device the anode actually points downwards.) At 0 ns, a strong beam of ions and electrons is generated and a first, strong X-ray pulse is emitted from the heated electrons. The subtle rings below the glowing blob in this contrast-enhanced image show that the plasma is undergoing what is called a "sausage" instability, in which the radius of the tube of current rapidly changes along its length. This instability causes rapid changes in magnetic field, which in turns cause a large electric field accelerating the electron and ion beams. This sausage instability is an undesirable one because it leads to a large loss of energy before the plasma is dense enough to produce many fusion reactions.

In frame 4 (12ns), the kink instability starts to twist the current path up into the dense plasmoid. The helical current path is visible in the lower half of this contrast-enhanced image. By 25 ns after the X-ray pulse, the current has twisted up into the tight, dense plasmoid in frame 6, about 200 microns in radius, which is continuing to move away from the anode. At this point the fusion reactions are at a peak and a second X-ray pulse and beam pair are emitted.

This sequence shows how FF-1 is functioning in the presence of continuing tungsten impurities that prevent the early formation of current filaments. They will be used as a comparison to those obtained with the beryllium electrodes, without any heavy-metal impurities. "With no heavy metal impurities, we expect that we will have current filaments during pinch formation. A tighter pinch will make the kinking instability speed up, so there won't be time for the sausage instability to form first," explains Lerner. "That will eliminate the loss of energy in the initial beam pulses and lead to much higher densities and more fusion yield."

Analysis of the data from FF-1's many instruments confirm that the shorter 10-cm anode is transferring energy into the pinch as efficiently as the 14-cm anode did in 2016 experiments. The new test matched the highest values of the old ones in total energy transferred to the pinch—over 10 kJ—as well as in X-ray energy emitted and in calculated plasma density. This is good news, as the beryllium electrodes are also 10 cm long. Lerner's calculations indicate that with low impurities, the shorter electrode length will lead to a higher current and thus higher fusion yield.

However, the experiments in 2017 and this past month did not achieve the goal of reducing the tungsten impurities sufficiently to create the current filaments, which would have led to much higher plasma densities and fusion yields. As pointed out back in LPPF's December 7, 2016 report, the filaments would survive only if tungsten impurities were reduced five-fold from 2016 levels to below 4% by mass. Despite microwave cleaning, the best values obtained in the current experiments were around 6% by mass, above the critical threshold required. Without greater density, no greater yields could be obtained either.

Fortunately, the oxides that have impaired the tungsten results will have little or no effect on the upcoming beryllium experiments. First, beryllium oxide is far more heat resistant than tungsten oxide. But more importantly, the very light beryllium nuclei, with only 4 positive charges, will have enormously less effect on the plasma than the tungsten nuclei with their 74 charges. The effect of impurities scales with the square of the electrical charge, so each beryllium ion has 300 times less effect.

Despite the continuing oxygen problems, the tungsten experiments that began in 2016 did lead to the publication of new world record results, as detailed in the next news item.

LPPFusion Publishes World Record Fusion Results in Leading Peer-Reviewed Journal, Physics of Plasmas

In a major step forward in the quest for safe, clean, cheap and unlimited energy, LPPFusion has published world record results in fusion energy. The new results, published in the October issue of the leading peer-reviewed journal *Physics of Plasmas*, demonstrated the highest confined mean ion energy of any fusion experiment in the world, an ion energy equivalent to a temperature of over 2.5 billion degrees C. This is over 200 times hotter than the center of the sun.

For comparison, this new record is **five times the highest temperatures confined with the tokamak device**, which has received the most funding from government fusion programs. LPPFusion uses the much cheaper and more compact dense plasma focus (DPF) device. The LPPF device, called Focus Fusion-1 (FF-1), fits in a small room and the heart of the device, a set of electrodes, is only a foot across. So far, LPPFusion, which is funded by investors, has spent $6 million on fusion research, far less than the billions already expended on tokamaks.

"Our new results, with a peak ion energy of 240 keV (kiloelectron volts), were a 50% improvement over our own previous record," explains LPPF President and Chief Scientist Eric J. Lerner, lead author of the paper. "In addition, we were able to achieve a 50% increase in the amount of fusion energy produced. This is a step toward our goal of producing clean, cheap energy with hydrogen-boron fuels." Hydrogen–boron fuel, also called pB11, is an ideal fuel, producing no neutrons, and no radioactive waste. Its energy can be converted directly into electricity, potentially greatly reducing energy costs below that from any existing source. Both hydrogen and boron are abundantly available. But the fuel needs extremely high ion energy—temperature—to burn. The new results demonstrate that FF-1 has achieved the energies needed to burn pB11 fuel.

The new advances were achieved by reducing the heavy-metal impurities in the plasma, the published paper explains. Such impurities impede the compression and heating of the plasma where the fusion reactions take place. Single-piece tungsten electrodes, among other innovations, led to the decrease in impurities.

“We still need to greatly increase the density of our plasma to get to our goal of more energy out of the machine than we put in,” says Lerner. “We expect to do that by entirely eliminating heavy-metal impurities next year. We’ll then be using electrodes made of beryllium, a light metal, so no heavy metals at all will be vaporized into the plasma.” By late 2018, LPPF also expects to be switching from the present experimental fuel, deuterium, to experiments with hydrogen-boron fuel.

Technical note on ion energy and temperature. Researchers use the term “mean ion energy” to describe how hot fusion plasmas are. To physicists, the term “temperature” only applies to objects near equilibrium, which does not always describe rapidly-changing fusion plasmas. However, a mean ion energy of 1 keV is equivalent to a temperature of 11 million degrees C.

Preparations for Beryllium, Boron Experiments

LPPF is preparing actively for both the experiments with beryllium electrodes expected in the spring and for the shift to hydrogen-boron fuel expected before year-end. The research team is planning the new vacuum system that will ensure that any beryllium dust the machine produces will be safely trapped in filters. As well, efforts are underway to ensure that the experiments will continue our high safety standard.

Based on data in the literature, the team recognized that a reaction of hydrogen and boron-10 would produce radioactive beryllium-7. With a half-life of two months, this isotope would certainly complicate any work with the device. To avoid any significant production of Be-7, Lerner calculated that 99.99% pure boron-11 would be needed. Naturally occurring boron is only 80% boron-11 with 20% boron-10.

Fortunately, due to the large 10% difference in mass between the isotopes, separating B-11 and B-10 is not that difficult. LPPF has already located at least one provider of 99.99% B-11. We are now searching for a second company to convert the pure B-11 to the compound of hydrogen and boron we need, decaborane ($H_{14}B_{10}$).

Publicity for Hydrogen-Boron Fusion

Popular knowledge of aneutronic fusion using hydrogen-boron (pB11) fuel took a step forward in December when science news outlets, and at least one newspaper, the UK’s Daily Mail, reported on research by Dr. Heinrich Hora and colleagues into laser-drive pB11 fusion. Dr. Hora’s group has been working for some years on this approach, as LPPF has reported in this newsletter. LPPF researchers have collaborated with some in the group, including a collaboration with Dr. George Miley on LPPF’s first experiments at University of Illinois. The press release from the University of New South Wales that lead to the coverage reported on the groups plans, not on any new results. We at LPPF look forward to getting similar publicity with our next new release!