Focus Fusion Eco Safe * Green * Clean * Virtually Unlimited * Cheap

Lawrenceville Plasma Physics, Inc

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

LPP Focus Fusion Report

April 6, 2016

Summary:

- **Bake-Out Succeeds in Cleaning Up FF-1**
- **Preionization Tests Prepare for New Hosts**
- **Focus Fusion in the Media**

Bake-Out Succeeds in Cleaning Up FF-1

LPP Fusion’s research team successfully completed the bake-out of the FF-1 experimental fusion device during March, reducing the oxygen in the device by about a thousand-fold. The oxygen had been an obstacle in reducing impurities in the plasma that produces fusion reactions, because tungsten oxide and its compounds with hydrogen are easily evaporated into the plasma. The bake-out took place from March 2 to March 23 at a temperature of 120° C, low enough to ensure that no damage was done to the plastic Mylar insulators.

During February, the team took a number of steps needed to prepare for the bake-out. LPPF Research Physicist Dr. Syed Hassan replaced the Rogowski coils that measure the ion beam. The new ones have a glass, rather than copper enclosure, to better protect the plastic insulation on the wires. The insulation itself was upgraded to Kapton, which can withstand the bake-out temperatures. Dr. Hassan also repaired the roughing pump that pumps most of the air out of the vacuum chamber, and a pressure gauge. In addition, he and LPPF Chief Scientist Eric Lerner tested the repairs of the main Mylar insulator to ensure that they could withstand the full 45 kV that they will be exposed to in firing the FF-1 device.

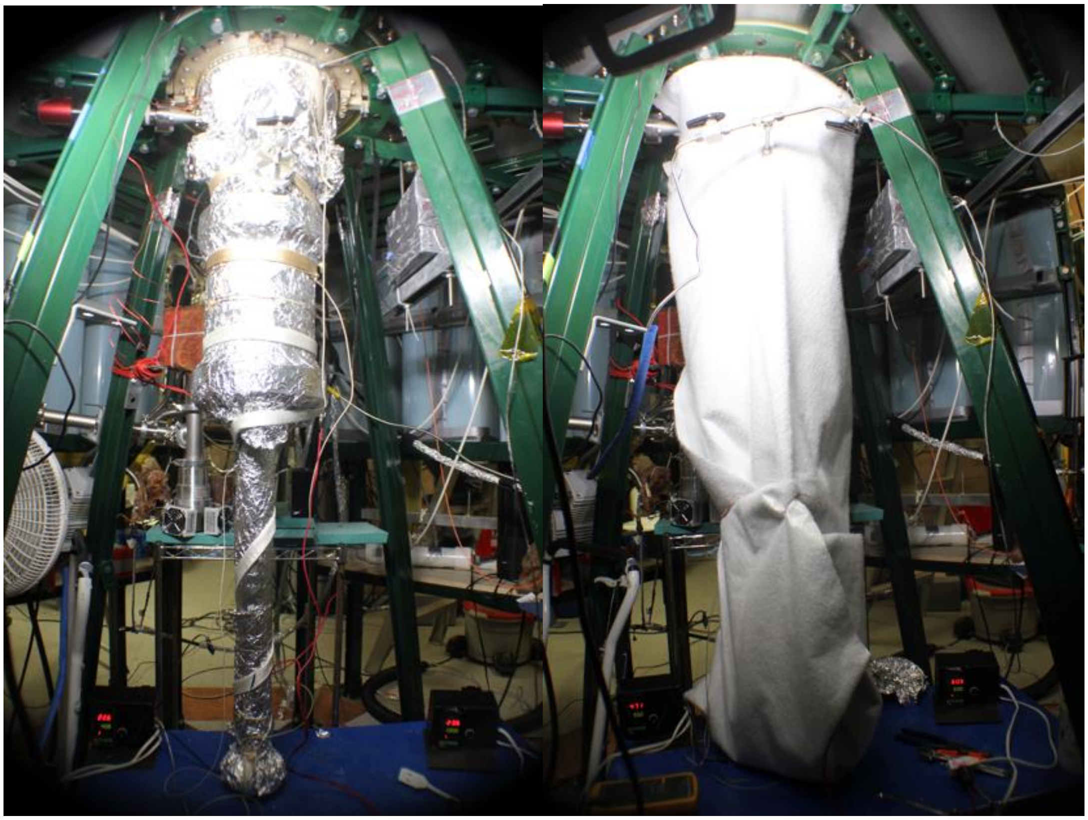

Fig. 1. FF-1 gets a warm blanket for bake-out. The vacuum chamber and drift tube were first wrapped with aluminum foil and heating tape, (left) and then more foil and an insulating blanket (right). Similar blankets with separately controlled heaters were made for the anode (heated from above the device) and the gas lines.

Hassan and Lerner then re-assembled FF-1, using a higher-purity ceramic insulator that has 50% more strength against electric breakdown. They installed a heating blanket with improved multiple thermostats to independently control the heating of the anode, cathode, vacuum chamber, drift tube and gas lines. Thick layers of aluminum foil distributed the heat evenly.

In the first day of bake-out about 40 milligrams (mg) of water vapor was removed, mostly the layer bound to the vacuum chamber—water that in the past released oxygen into the plasma. (This may not sound like a lot, but the total mass of the plasma carrying the current during FF-1 shots is only 3 mg.) In the subsequent nearly three weeks of bake-out a comparable amount of water was baked out, mainly from a large disk-shaped silicone gasket that helps seal the chamber.

We estimate that water remaining, mostly deep within the gasket, is only 100 micrograms. In addition, a single atomic layer of oxygen with a mass of about 40 micrograms is tightly bound to the surface of the tungsten. This will only come off when the plasma lifts it off during a shot. However, as the plasma cools, about three-quarters of the oxygen will be absorbed by the titanium nitride coating on the vacuum chamber, so the remaining oxygen on the tungsten will drop below our goal of 10 micrograms in only a few shots.

Of course, oxygen leaks from the atmosphere can't be entirely eliminated, but we have reduced that source to less than 2 micrograms per hour. During the course of a day of firing, oxygen should be reduced to very low levels, reducing one main source of impurities to less than 1% of the mass of the current sheath.

Preionization Tests Prepare for New Shots

The second main source of impurities in previous FF-1 shots has been vaporization of the anode material by runaway electrons. These high-energy electrons occur very early in the pulse, when the plasma has not yet become fully ionized—in other words, when only a few electrons are free to move outside of atoms. The cure for these runaways that the LPPFusion team has proposed is preionization: a very small initial pulse of current smooths the way for the big pulse by producing lots of ionization—many electrons free to move. This is like deliberately producing an electron traffic jam—many electrons moving slowly rather than a few moving so fast that they can vaporize tungsten.

After the successful bake-out, Hassan and Lerner turned to testing the preionization, recording the shots with video cameras. The images showed that the preionization currents were flowing in narrow bands, only about 0.5 mm in radius, opposite each cathode vane. This is good news, because it means ionization levels will be high (good traffic jams) and the main current will also be tightly concentrated, encouraging filament formations, which in turn leads to higher density plasmoids and more fusion reactions. However, they also found that in some conditions, the preionization occurred unevenly, concentrated at some of the cathode vanes but not others. That would lead to asymmetrical main pulses and poor compression of the plasma, thus poor fusion yields. By varying the current supplied to the preionization pulses and the amount of time between them, the team was able to obtain symmetrical preionization, as shown in this video. The video was taken from a window looking up at the electrodes from a little off-axis, which shows almost half of the circle of vanes on the cathode. The team is still studying and optimizing the preionization process.

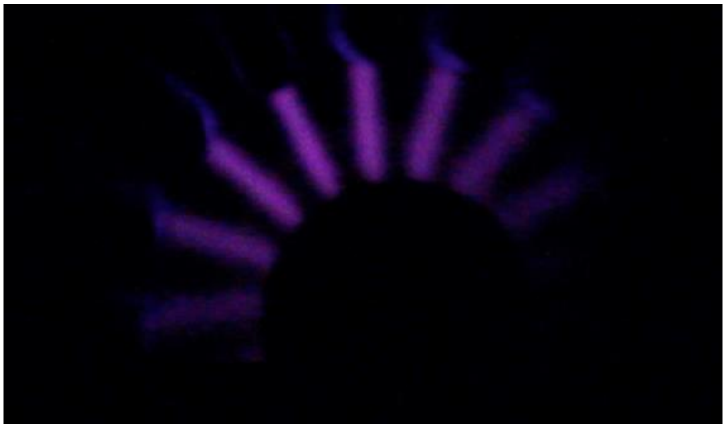

Fig. 2 A preionization pulse lights up the plasma between the tungsten cathode (outer circle) and anode (inner circle). Each glowing line connects with one cathode vane. From this window about half of the 16 vanes are visible. The left- and right-most discharges appear dimmer only because of the perspective of the camera.

During the preionization tests, a couple of electrical components failed in the power supply system that feeds current to the capacitors. As a final step in preparing for new shots, the team is replacing these components with more robust ones that can hold off higher voltages.

While these tests were ongoing, Chief Information Officer Ivy Karamitisos and IT associate Jose Varela upgraded the data system that will record, process and back-up data from the shots. They also improved communication links with several instruments, including the Residual Gas Analyzer that measures oxygen and water levels in the chamber, and a new Geiger counter, which will be used to detect short-lived radioactive isotopes produced during shots.

Focus Fusion in the Media

While this report overlooked it in our Jan. 22 edition, on Jan. 3, 2016, the Chicago Tribune ran an editorial pointing to privately–funded fusion power initiatives, including LPPFusion's, as possible solutions to the world's energy problems. The editorial, entitled "*Will a private-sector fusion solution meet all of our energy needs?*", critiqued long-term skepticism about fusion in light of the rapid progress achieved recently in the fusion field, quipping, "What sounds too good to be true just might be...true." It continued: "Now comes new reason for hope: a slew of private-sector startup companies are racing helter-skelter to deliver what university and government researchers have not…As this private-sector effort accelerates, expect to begin hearing the names of now-obscure companies—Industrial Heat, Tokamak Energy, Lawrenceville Plasma Physics, Helion Energy and others hoping to become as dominant in their nascent field as Westinghouse (1886) and General Electric (1892) were in the early electrical industry."

Focus Fusion also appeared in Commentary magazine's March 16, 2016 issue. In a letter to the editor, LPPFusion Board of Advisors member Alvin Samuels pointed out that the water shortage in the Middle East could be solved by desalination of sea water with the unlimited cheap energy that Focus Fusion would make possible.

Photo of the Month

Fig. 3 While this view inside the vacuum chamber may look red-hot, the bake-out was actually nowhere near that. The red color results from the interaction of the golden color of the titanium nitride on the vacuum chamber and the camera's color correction software, but we thought it looked great. The inner anode is surrounded by the insulator, the vanes of the cathode and the axial field coil, which provides a small but vital initial magnetic field. For video of the initial assembly of the tungsten electrodes last year, please visit Focus Fusion Society here.