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

LPPFUSION.com

LPP Focus Fusion Report
February 22, 2017

Summary:

- **New Experiment: Optimizing Microwaves to Reduce Oxide Impurities**
- **Beryllium Cathode Nears Completion**
- **LPPFusion Statement on US Immigration**

New Experiment Starts: Optimizing Microwave Treatments to Reduce Oxide Impurities

Focus Fusion-1, LPPFusion's experimental fusion device, resumed firing January 30 to start our final set of experiments with tungsten electrodes. Our initial results showed that we still need more work to reduce the tungsten oxides that have fed impurities into our plasma. We are now optimizing the microwave treatments that can strip oxygen off the electrodes. In the meantime, we have succeeded in getting our ultra-fast ICCD camera to work, and are improving its timing to get sharper images.

In January, the LPPFusion research team completed the reassembly of FF-1, using a fresh 10-cm long tungsten anode and the existing 14-cm long cathode. We successfully performed a bake-out, warming the chamber to 60 C for a week to remove water vapor from inside the chamber. We then applied a microwave treatment to heat a stream of hydrogen to strip oxygen from the tungsten oxide layers on the electrodes. The microwaves heat the gas to thousands of degrees C, hot enough to break the hydrogen molecules apart and form free hydrogen atoms (each hydrogen molecule contains two atoms). The isolated hydrogen atoms are highly chemical reactive, and strip oxygen from the tungsten oxide to form water vapor. This vapor is then continuously pumped out. Removing the oxides is critical, since tungsten oxide breaks down easily with heat, releasing undesirable tungsten impurities into the plasma.

We monitored the oxygen removed, using a residual gas analyzer. After 14 treatments (each lasting only a couple of minutes) we saw a many-hundredfold reduction in oxygen released. So we were fairly confident that there was little remaining oxide in the chamber. We then proceeded to successfully test the pre-ionization system. This system, releasing a tiny current between the electrodes, is designed to smooth the path for the main current pulse, reducing erosion that leads to impurities and making for an even start to the pulse all around the anode. We were able to take photographs of the glow from the pre-ionization (Fig.1) showing it was working properly.

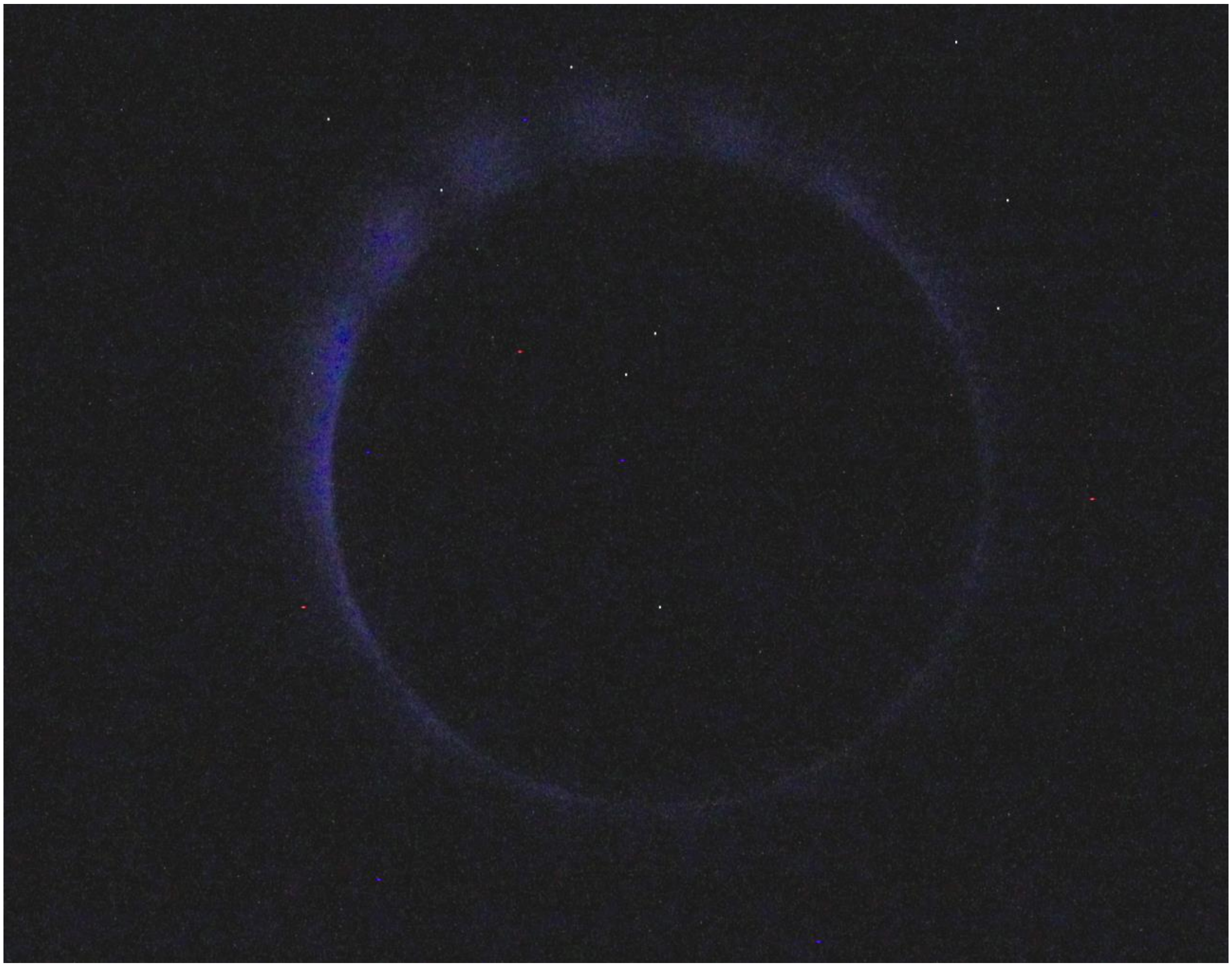

Fig. 1. Looks like a total solar eclipse, but it's not! This is a photo of the ghostly glow of preionization from the end of our tungsten anode. The anode is the black circle in the middle and the "corona discharge" from a tiny current is creating the violet glow around the anode. When we fire the machine, these ionized regions will smooth the path of the million-amp current, reducing vaporization from the anode and thus impurities in the plasma.

At the end of January we resumed firing FF-1. We expected that, with little or no oxygen in the chamber, we would not see a large increase in pressure, or pressure “pop,” after we fired the first shot. (A small increase would happen just due to the increase in temperature.) But research is the realm of the unexpected, and the pressure after the first shot went up by 2 torr, or 5%, triple what we expected. We also saw in the optical spectrum from the shot the telltale bright line of oxygen at a wavelength of 775 nm. Where did this come from?

The spectrometer gave us the clue to the answer. In the first few shots, we also saw the clear lines of helium. Helium is very rare in the atmosphere, and the only possible source was the helium gas we had used weeks earlier to test for leaks in the chamber. In these tests, helium gas is puffed on the outside of the chamber. If the gas is drawn inside by a leak, the residual gas analyzer detects the helium and the leak is revealed.

Evidently, gas that was trapped near the various vacuum seals was released into the vacuum chamber when FF-1 fired and vibrated the chamber, opening the trapped regions. Such “burps” are very hard to avoid without a much more sophisticated vacuum chamber and a significant engineering effort. These burps let in not only helium, but also water vapor and air, both containing oxygen. Following the shot, some of the oxygen reacted with the still-hot electrodes to form the tungsten oxide we have been trying to eliminate.

So we now had to return to the microwave treatments to remove the newly-formed oxide layers. Our initial efforts only led to a reduction of oxygen to about half that achieved in our best results in 2016. This was not enough—we need at least a ten-fold reduction. Clearly the microwave treatments were not working as well as they had before we fired.

Fortunately, we are able to monitor the microwave treatments by the glow they produce in the chamber. (Fig. 2) These images showed us that the distribution of the hot gas was highly sensitive to the exact position and orientation of the microwave-producing magnetron in the vacuum chamber window, the pressure of the gas, its flow rate and other variables. Experiments by other researchers on microwave heating of hydrogen showed that lower pressure leads to greater penetration of the microwaves into the gas, but higher pressure leads to higher temperatures, so a careful optimization of both must be achieved. Right now, we are proceeding step-by step to get such optimized conditions and removing the oxides before firing more shots.

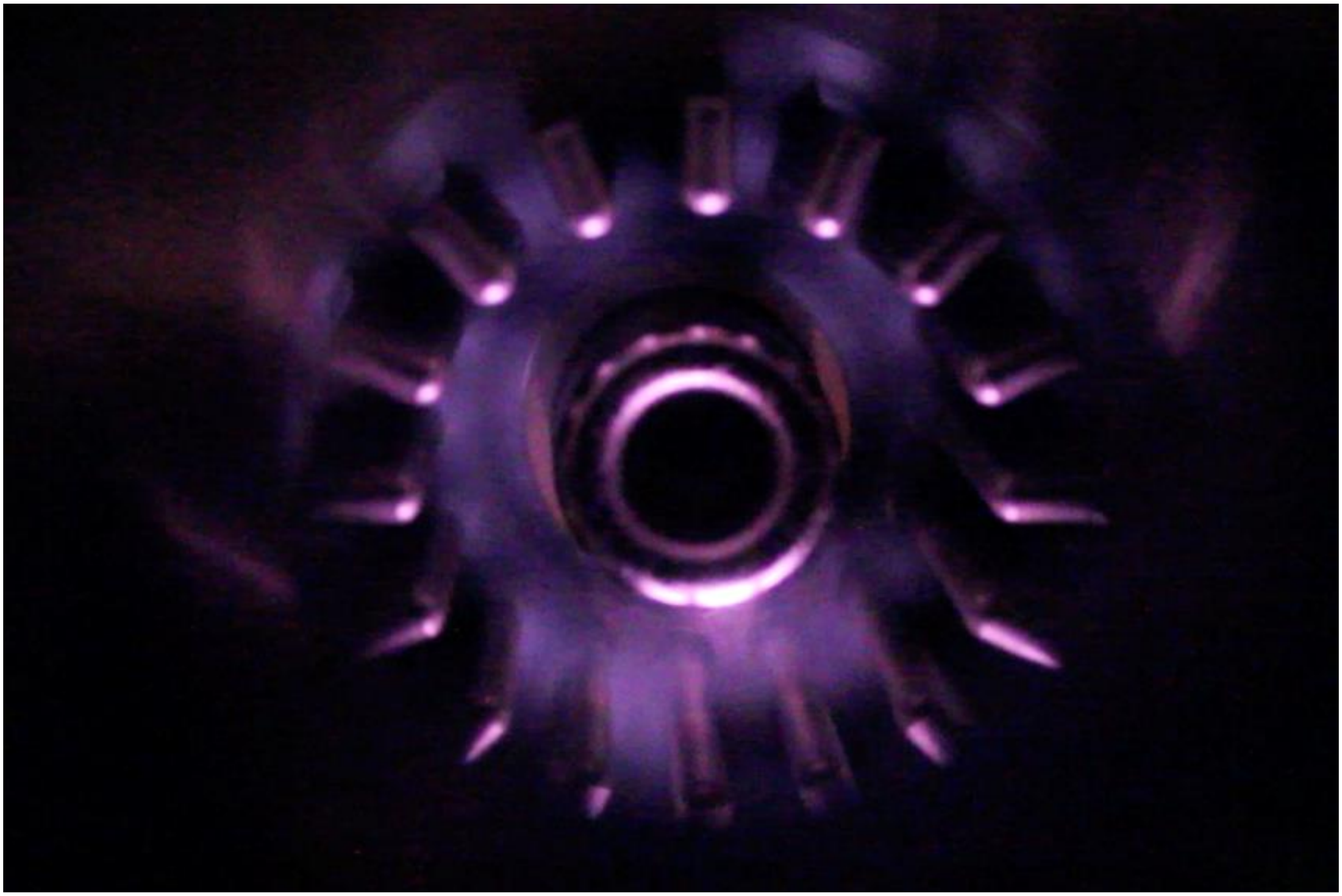

Fig. 2 Microwaves generate the hot glowing plasma between the anode (inner cylinder) and cathode (outer vanes), which removes oxygen from tungsten oxides. But we need to make the coverage of the plasma more even to get all the oxides off.

Since the treatments take such a short time, we don't need perfect functioning for each treatment. If even half the oxides are removed with each treatment, a thousand-fold reduction can be achieved with ten treatments. But we do need to ensure that oxygen is being removed, not simply moved from one spot to another. This may take a few weeks, but it will be worth it to achieve our goal of at least a ten-fold reduction in the tungsten impurities in the plasma. At that point we expect to see the plasma filaments that are the first stage of compression of the plasma, higher density in the plasmoid where the fusion is produced, and much higher fusion yield.

During the small number of shots we have fired, we did succeed in showing that the ICCD camera now works (fig. 3). The camera had been disabled last year due to increased electromagnetic pulses from FF-1, which entered the camera through its power cords. Research Physicist Syed Hassan was able to counter this electromagnetic interference by putting two large batteries into a metal box (Faraday cage) with the ICCD camera, providing a power supply that was entirely protected for the radio-frequency pulses. Now we are improving the timing of the camera shots to get a sharper picture of the central plasmoid. We expect to reduce the exposure time from a "long" 30 ns (billionths of a second) to a short 0.2 ns to freeze the fast action when the plasmoid forms. Such short images should give us a good measurement of how big the plasmoid is and thus, indirectly, a measure of how dense a plasma we are forming.

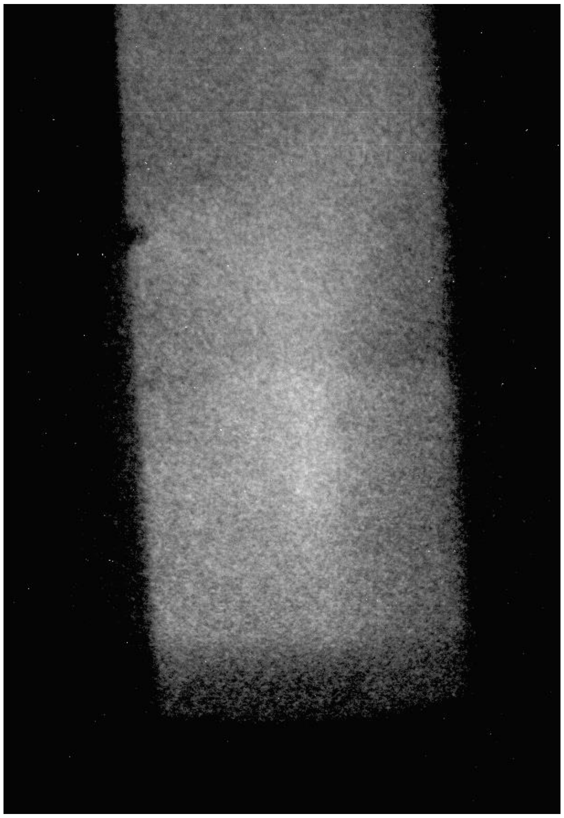

Fig. 3 ICCD image of shot 4, Jan 31 2017, exposure time 200 ns. The image shows the 1-cm wide region visible between two adjacent cathode vanes, on the axis of the device. The image is inverted, with the end of the anode at the bottom of the image. The bright central region is the pinch, containing the plasmoid, which is considerably blurred by its rapid vertical motion during the exposure. We expect soon to get much sharper images with shorter exposures.

Beryllium Cathode Nears Completion

Hardric Labs in Massachusetts has reported to LPPFusion that its work on machining the new beryllium cathode (fig.4) is nearing completion and they expect to ship the finished piece in early March, only a few weeks behind their initial schedule. Since the beryllium anodes have already been received at the Middlesex NJ lab, we will soon have a complete set of beryllium electrodes ready for our next set of experiments. This will be an important milestone for the project, as our effort to obtain the beryllium electrodes began in mid-2014, as soon as our crowdfunding effort had raised the money needed for the new set. Beryllium is crucial to the next step in the experiment for two reasons. First, as a light element with an atomic charge, or "z", of only 4, it will eliminate any high-z impurities in the plasma, optimizing FF-1's performance. Second, beryllium is highly transparent to x-rays, so will be much better able to withstand the heavy x-ray flux from the plasmoid as we increase fusion yields.

Once our current experiments with tungsten are complete, we will still need two or three months to prepare for the beryllium experiments. For one thing, our vacuum chamber will need a new coating of titanium oxide to coat over any remaining tungsten in the chamber. But with the electrodes soon to be in hand, we can be confident that the next set of experiments will be under way in the summer.

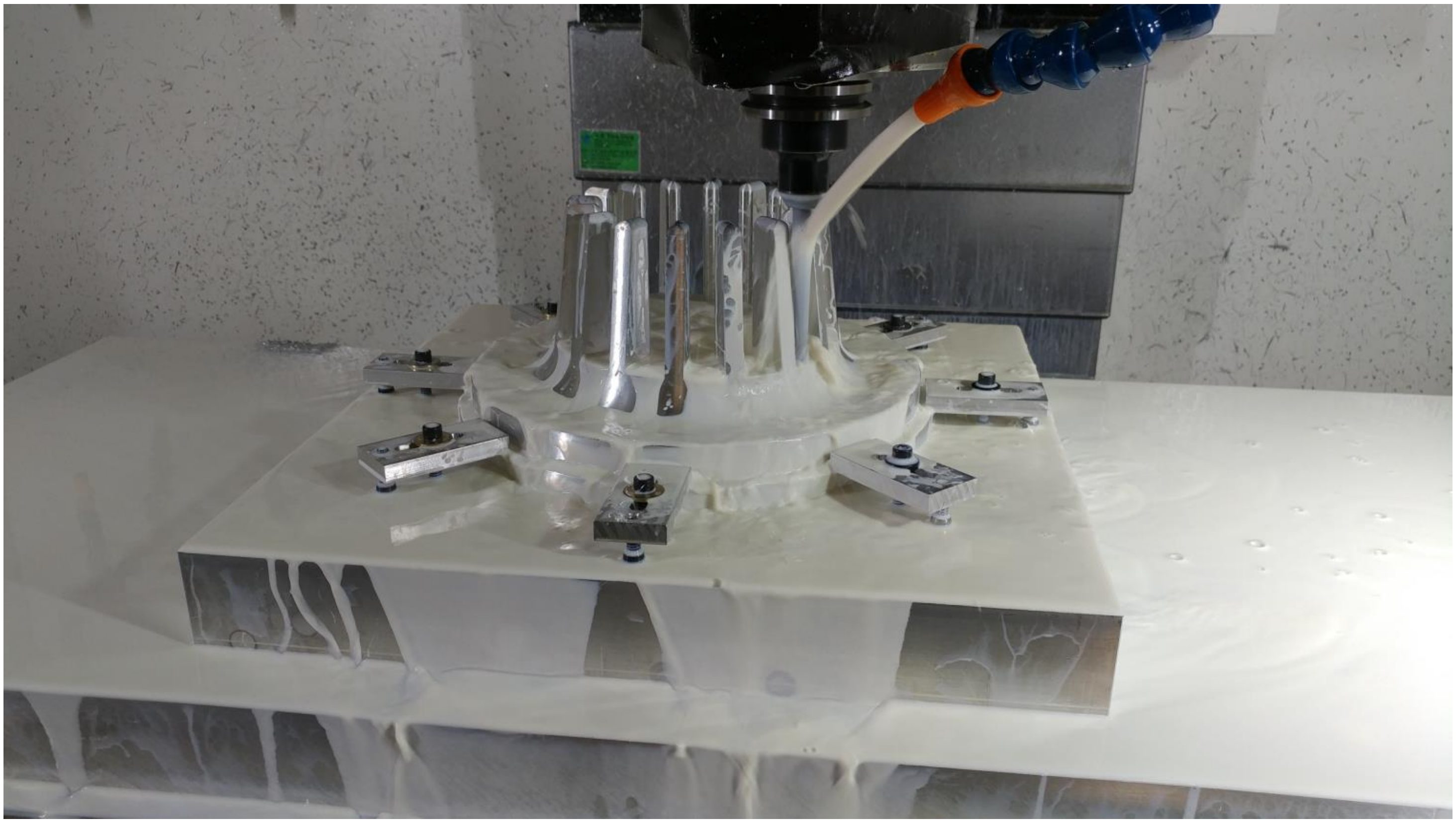

Fig. 4 Beryllium cathode for next experiment being machined at Hardric Lab. In Mass.

LPPFusion Statement on US Immigration: We Support Freedom of Movement for ALL

LPPFusion joins with hundreds of high-tech firms and tens of millions of people in condemning President Trump's Executive Order banning entry from seven nations. We support the inalienable right of freedom of movement for all.

Eighty percent of LPPFusion's team are immigrants, born outside of the United States. We are part of the great global tradition of scientific and technological advance that relies on the movement and collaboration of researchers across all borders. But our work has been repeatedly harmed by US immigration laws. Two of our former senior researchers have left the United States because they were unable to gain permanent resident status for themselves and their families. Our present staff's travel plans have been disrupted by Trump's executive order.

We also oppose the present immigration laws of the United States as unjust, unconstitutional and harmful to all who live here. They have caused, and continue to cause, suffering not only for undocumented immigrants, but for documented immigrants, permanent residents, and citizens, both foreign-born and native-born. Attacks on immigrants' rights undermine the rights of all who live here. These laws must be repealed.

Open immigration was, after all, the original “immigration policy” of the United States. Up until 1879, it was the policy of the United States to, in the words of an 1868 treaty between the US and China, “recognize the inherent and inalienable right of man to change his home and allegiance, and also the mutual advantage of the free migration and emigration of their citizens and subjects, respectively, from the one country to the other for purposes of curiosity, of trade, or as permanent residents."

Today, just as in 1868, nothing in the US Constitution gives the US government the power to violate this “inalienable right” to freedom of movement or to control who comes here or who leaves. The present immigration laws are all unconstitutional.

We will work with all to protest these policies through petitions, demonstrations and other means. We are confident that, with sufficient mass action, we will not only block these new policies but we shall overcome the broader injustice of anti-immigrant laws.