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Lawrenceville Plasma Physics, Inc

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

LPP Focus Fusion Report
May 31, 2017

Summary:

- **Microwaves vs Oxides Fight Heats Up**
- **Beryllium Cathode Getting Final Touches**
- **Thanks for Fund-a-Shot**

Microwave vs Oxide Fight Heats Up

The LPP Fusion research team's ongoing effort to clean off the oxides from the electrodes of our FF-1 experimental fusion device has made progress, but is not completed yet. We've succeeded in doubling the temperature of the microwave-heated plasma that does the cleaning. We also have convincing evidence that the oxides are still the source of the great majority of the impurities in the plasma. But to remove all the oxides, we need to increase our microwave power to get still higher plasma temperature, which is what we are doing now.

In March, we initially upgraded the waveguide that connects the magnetron, which produces the microwaves, to the window of our vacuum chamber. When we connected the magnetron to the large quartz window, we were able to get a bright glowing plasma by heating deuterium gas at low pressure, between 0.1 and 0.5 torr (atmospheric pressure is 700 torr). We could use the optical spectrum obtained from that glow to measure the temperature. Hydrogen produces a series of well-known lines in its spectrum and by measuring the ratio of the intensity of these lines, we could measure the temperature of the electrons in the plasma. It turned out to be around 5,000 K. While that sounds hot for an ordinary microwave-oven magnetron, it was not hot enough. We knew from published papers that the best results for oxide cleaning require about 20,000 K. At that temperature, the electrons have enough energy to allow the hydrogen atoms to strip the oxygen away from the tungsten.

In April, to add more power, we attached a second magnetron to the small window that is on the opposite side of the vacuum chamber from the quartz window. With both magnetrons operating, we got a much brighter glow (Fig. 1) and the spectrum indicated a doubling of temperature to around 10,000 K. In addition, once we started firing, we found that the yellow oxide color that had earlier appeared on the outer surface of a few vanes had disappeared.

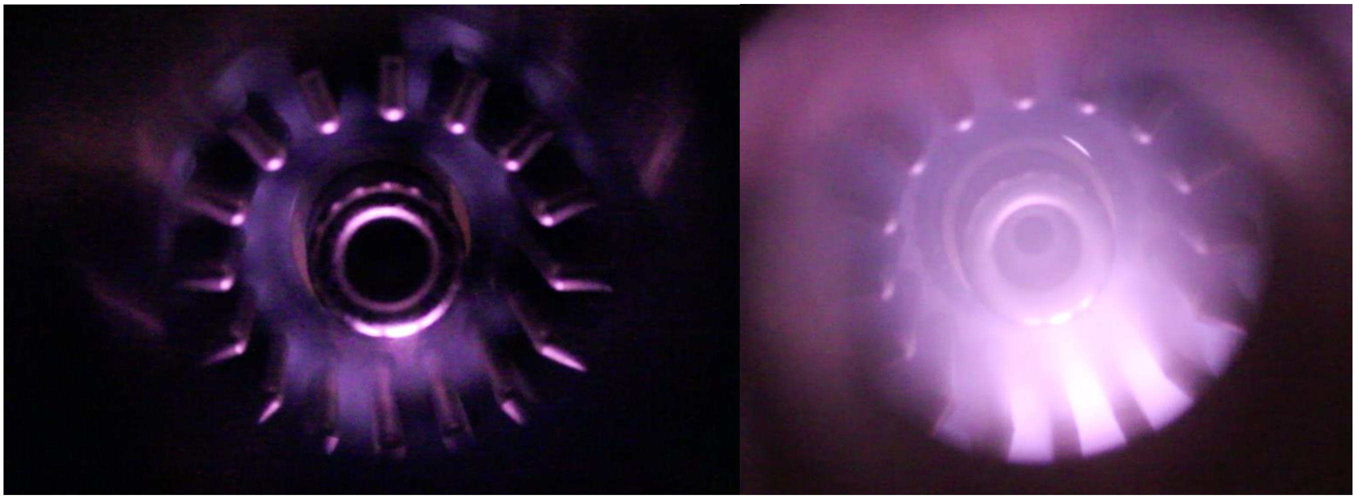

Fig. 1. Getting hotter—The new microwave test with two magnetrons (right) shows a much hotter, brighter plasma than the earlier tests with one magnetron (left). But the heating is still unevenly concentrated towards the large quartz window (direction of brightest region on right) and more power is needed to spread the hottest regions to all parts of the electrodes.

It was still not enough to get rid of all the oxides. We used the spectrometer to measure the lines of oxygen and tungsten during the shots and we varied the deuterium fill pressure from 9 torr to 38 torr. To eliminate any influence of how bright the overall spectrum was, or how much light was absorbed by the window, we measured the ratio of the line intensity to the intensity of the background continuum light at the same part of the spectrum. We found that the oxygen lines were now only one third as big as they were in our 2016 experiments (Fig.2), about two-thirds what they were in February. But after several tests of the microwaves, the oxygen lines stopped going down.

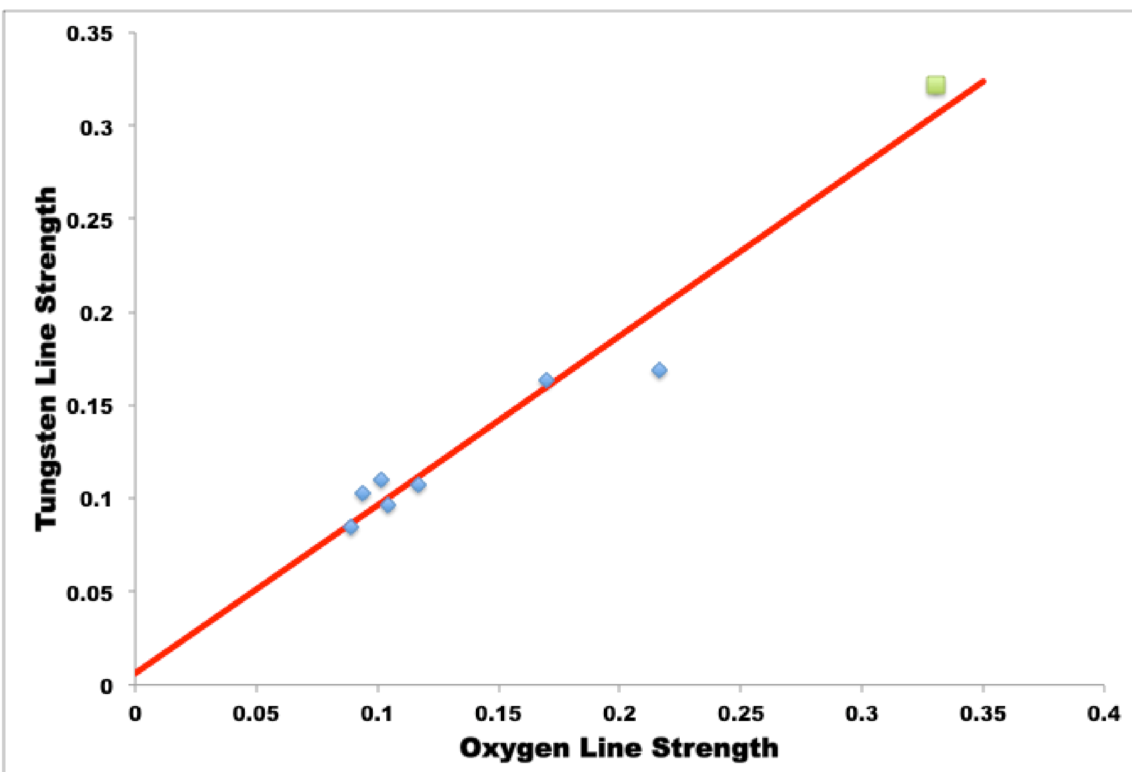

Fig. 2 Tungsten line strength as a fraction of continuum spectrum is proportional to oxygen line strength, indicating both impurities come from tungsten oxide. The blue dots from 2017 shots show the reduction in impurity from a typical 2016 shot (green square).

On the positive side, we observed that the intensity of the tungsten lines was always closely proportional to that of the oxygen lines, indicating that the concentration of tungsten and the concentration of oxygen were also proportional to each other. That was encouraging, because that is what we would expect if nearly all the tungsten impurities in the plasma were coming from the breakup of tungsten oxide. So this implies if we can get rid of the oxygen, we can get rid of the tungsten impurities as well. It also implies that the preionization is working well enough to protect the pure metallic tungsten. (The tungsten oxide breaks up at only 500 C, so is too fragile to be protected by any means—that's why we need to get rid of it.)

With continuing impurities in the plasma, we could not get the filaments to form that we need to improve yield. In the current series, the highest yield shot had only 60% the fusion yield of the record shot of 2016. As we have expected, yield can't improve until we get impurities below a critical threshold, which requires reducing them by another factor of three. However, we did succeed in getting good shot-to-shot repeatability, with shot yield and other plasma parameters varying only by about plus or minus 15%. This good repeatability is also an indication that the preionization is working well to create a symmetrical start of the pulse and eliminating unevenness, which was a main source of shot-to-shot variability.

We believe that oxides on the part of the electrodes farthest from our quartz window are not in contact with sufficiently hot microwave plasma to be eliminated. The problem is that the diameter of the small window on the other side is less than half the 12-cm wavelength of the microwave radiation we are using. That is too small to transmit the radiation well, so most of the radiation does not get through. To get the full 2 kW we need, we must put all of the microwaves through the large quartz window. We are now working to do that. We will put two magnetrons on a Y-shaped connector to funnel their power together. We hope then to have the 20,000 K we need to eliminate the oxides everywhere.

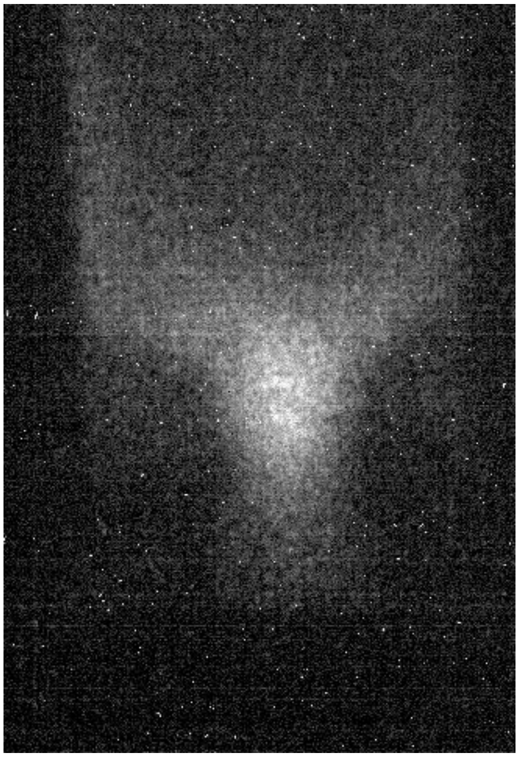

Fig. 3 An ICCD short-exposure image of the plasmoid formed during shot 2 of May 23. The width of the frame is 1.3 cm. The brightest central region is the plasmoid, about 500 microns in radius. Note filaments extending up from plasmoid, indicating image resolution better than 100 microns.

Beryllium Cathode Needs Final Touches

While we had expected to receive the beryllium cathode in mid-March, the part did not pass Hardric Labs' internal inspection. The machining tool had inadvertently bounced off the bottom of each of the 16 vanes that are the main parts of the cathode, creating tiny nicks on the neighboring vanes. Since the machining process is entirely automated, and this occurred during the last step of machining, this problem was not found until inspection. With the help of Rudy Fritsch, LPPFusion's Chief of Investor Relations and a highly experienced mechanical engineer, the LPPF team came up with a fix that smooths off the nicks and may even improve the cathode's performance. The fix requires a custom machining tool, so some additional delay in the part's completion is expected. However, the beryllium cathode will be crucial to the next set of experiments, so getting it right is worth the time. The nicks would have created sharp surfaces that could concentrate the electric current and possibly disrupt the filaments that are needed for high performance.

Since beryllium is a very light atom, with only four electric charges, we expect none of the impurity problems we have had with earlier materials. The effect of impurity ions on the plasma is proportional to the square of the atomic charge, so beryllium has 300 times less impact on the plasma, ion for ion, as tungsten. At the same time, the tungsten experiments will allow us to start the beryllium experiments with a close-to-optimized preionization system, so our continued tungsten experiments will contribute to the success of the beryllium series.

Fund-A–Shot—Thanks, and Let's Do More

To get our research done, we need funds. Most of our resources still come from investors, but contributions are greatly needed as well. In the last few months generous contributors have funded several of FF-1's shots—see our Fund-a-Shot page on our website. We thank these contributors for their help in making Focus Fusion a reality! But we need more help. To make the fastest progress we can, we need more funds to hire at least one more researcher. In addition, we want to look ahead and start purchasing long lead time material, especially beryllium, for modifications to our electrodes that will be suggested by future experiments. To do this, we need several streams of cash flow.

We hope very soon to enlarge our investor pool by using the new crowdfunding equity regulations to sell shares to smaller investors in the United Sates. But these regulations will limit the total number of these smaller shareholders to 500 individuals. Getting these 500 small investments will be crucial to our plans and we hope to raise $1 million this way. But we know that far more than 500 people in the world already want to help fusion to become a cheap, clean, safe and unlimited energy source. Two thousand people contributed in 2014 to our Indiegogo campaign. We will still need those contributions. If we could, for example, get 20,000 people to contribute just $2.50 a month, we could fund our entire present budget, and use investments to hire more people and to make the advance purchases we need. So, if you have not contributed to LPPFusion, please consider doing so now. Getting to fusion sooner will help everyone on earth.