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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
July 9, 2015

Summary:

- **Focus Fusion-1 Resumes Firing With Monolithic Tungsten Electrodes, Pre-ionization**
- **Impurities Down, But Not Yet Enough—More Shots Needed**
- **New Summer Research Associate Joins LPPFusion**

Focus Fusion-1 Resumes Firing, First Mega-Amp DPF To Use Tungsten Electrodes, Pre-ionization

On June 16, LPPFusion's Focus Fusion-1 (FF-1) device resumed firing, after a hiatus of 19 months. It became the first dense plasma focus device of over 1 meg-ampere current to use monolithic tungsten electrodes, or to fire with pre-ionization. (Pre-ionization involves using a small current to smooth the way for a larger one.) So far, only a dozen shots have been fired, too few to reach any firm conclusions. However, very preliminary results indicate that impurities have dropped significantly with the new design, but not yet far enough for dramatic gains in fusion yield.

The resumption of firing was made possible by the successful full repair of the tungsten cathode and the flawless assembly of the new cathode into the FF-1 device. In late May, LPPFusion CIO Ivy Karamtisos bridged over remaining micro-cracks in the tungsten cathode rim with indium metal (video coming soon). The soft indium cold-welded onto the tungsten providing a low resistance path for the electric current to flow into the cathode. Next, Karamtisos, Chief Scientist Eric Lerner and Research Associate Mark Klapheke carefully applied indium to the entire cathode rim, and then bolted the steel connecting plate onto the cathode. The steel plate actually attached to the steel brace that had previously been glued onto the tungsten cathode, with the tungsten current contact and its soft indium coating squeezed between the two steel pieces. The results were extremely low electrical resistance, no more at any point than18 micro-ohms, and good mechanical strength. This ensures that the cathode can safely take up to 1.6 MA of current, enough for the planned experiments.

The lab team then mounted the cathode steel plate assembly into the experimental device. Using the new micrometer tabs, the team centered the cathode on the anode to a precision of 25 microns (one thousandth of an inch.) (Figure 1) After fully assembling the vacuum chamber, the team was able to achieve a low leak rate of only 35 microtorr per minute. (At this leak rate it would take 38 years to fill the vacuum chamber back to atmospheric pressure!)

While assembly was completed June 3, teething problems to be expected with restarting an experiment after a year and a half hiatus slowed final preparations for firing. Then the new triggering system needed for pre-ionization required testing and fine-tuning, the ICCD camera was in need of maintenance (and still is) and other minor problems had to be addressed. The first shot was finally achieved on June 16th. As expected it produced no fusion. This is because the first shot coats the insulator with a thin, discontinuous layer of metal. In further shots, this coating then guides the electric current in a thin sheath, necessary for the formation of the plasmoid—the dense knot of plasma that is heated to fusion temperatures. On the third shot, however, on June 19th, the first plasmoid and fusion reactions took place, inaugurating LPPFusion's new experimental series.

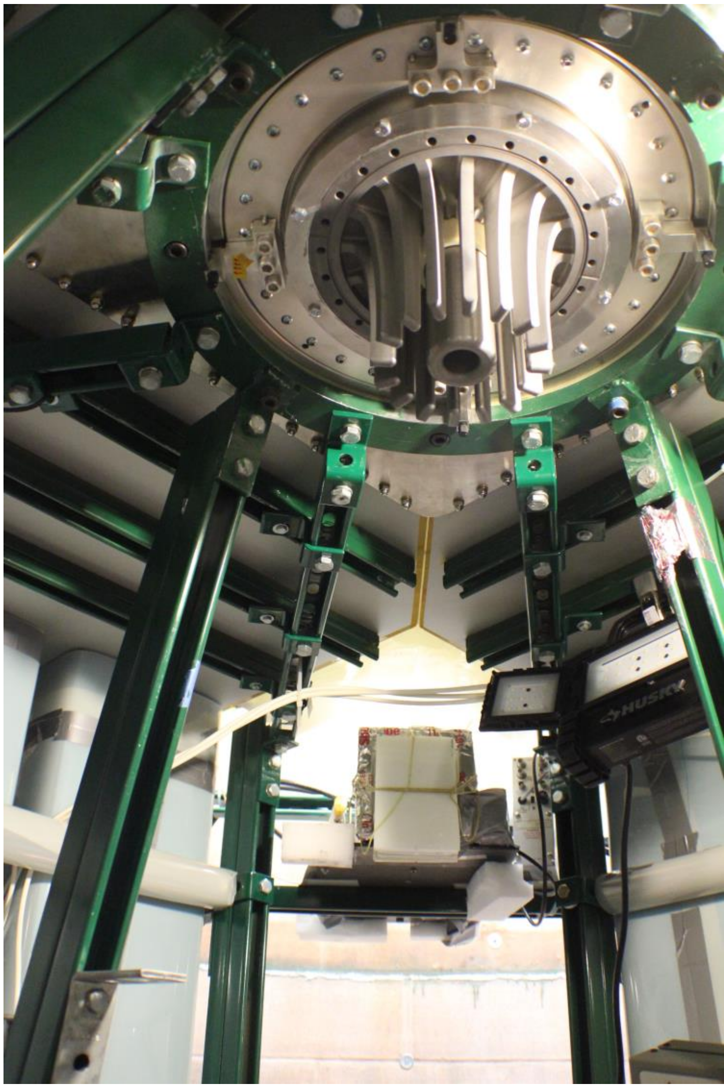

Figure 1: *The newly assembled tungsten cathode (outer ring of vanes) and anode (inner hollow cylinder) successfully assembled into the FF-1 device. The rectangular object below the electrodes is the silver activation detector—one of the main instruments for measuring the neutrons produced in deuterium fusion reactions. photo-Erin Lerner*

Early Shots Show Impurities Dropping, But Not Yet Enough For High Fusion Yields

With just a dozen shots performed so far, we can draw only very preliminary conclusions from our results. The first is that impurities do indeed seem to have dropped significantly with the new electrodes—the first main goal of the new experiments. Impurities appear to be the basic obstacle to high fusion yields, as they disrupt the filaments that are the first stage of compression of the plasma. The optical spectra obtained in the new experiments show peaks at wavelengths characteristic of tungsten, but at roughly ten times less abundance than the copper and silver impurities seen in shots with the old electrodes (Figure 2).

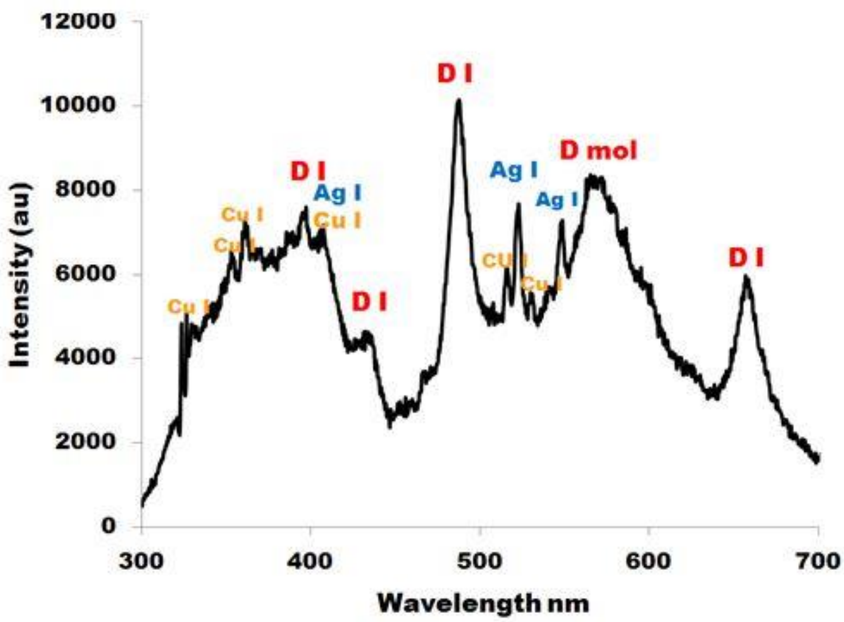

Figure 2a

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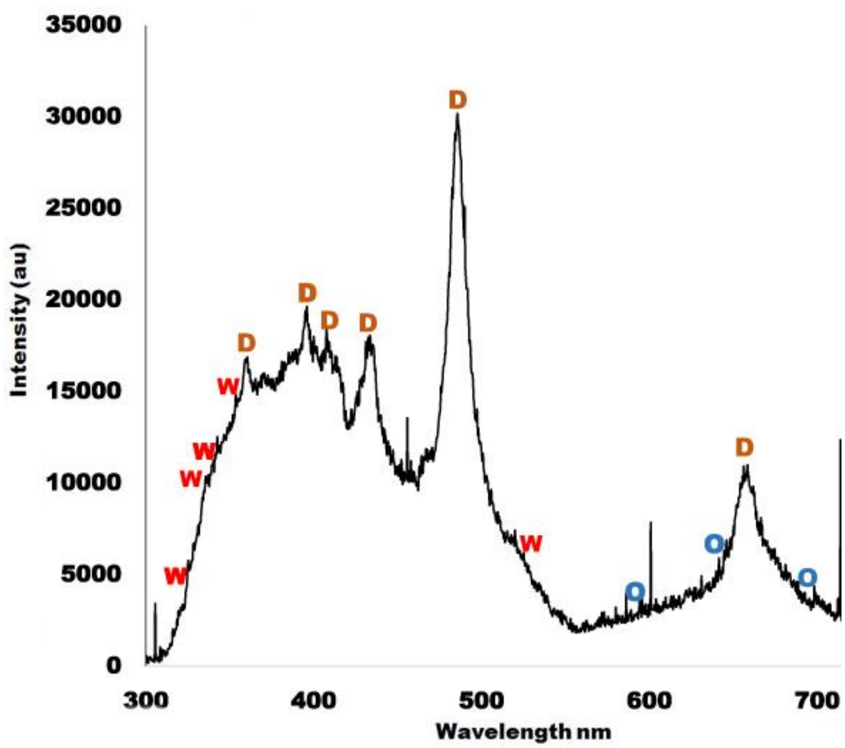

Figure 2b

Figure 2 - *The decline in impurities in FF-1's plasma with the new tungsten electrodes is shown in this pair of optical spectra. In Figure 2a, top, the spectrum from the old electrodes show large copper(Cu) and silver(Ag) lines. The new spectrum from the tungsten electrodes, Figure 2b, bottom, shows much smaller tungsten (W) and oxygen (O) lines. Overall, impurities have dropped by about a factor of ten. The large molecular deuterium band has also disappeared in the new spectrum,indicating a hotter plasma.*

Additional evidence is the much smaller amount of x-ray energy emitted for a given amount of fusion in the new experiments. X-rays are produced when electrons are sharply accelerated in collisions with ions—the nuclei of atoms. Since the metal impurity ions have a much higher electrical charge than the deuterium ions in the plasma (74 atomic charges for tungsten versus only 1 charge for deuterium) their collision with electrons produce far more X-rays —in proportion to the square of the atomic charge. For a given amount of fusion reactions, the amount of x-rays increases with increasing impurity levels. Observations of x-rays and neutrons with the new electrodes confirm a roughly tenfold decrease in the number of impurity ions.

While a tenfold reduction in impurities—to about one impurity ion for 500 deuterium ions—is a good start, it is not what Lerner calculated would be needed to preserve the filaments, nor what theory and previous experiments indicate can be achieved. For that, a 50-100 fold reduction in impurities is required, or 5-10 times less impurity than that has been achieved so far. Indeed, the initial results show the same symptoms of impurity—an "early beam" before the main pinch, and a slower motion of the current sheath, as had been observed with the old electrodes, although the early beam seems much smaller in the new shots. Given continued impurities, it is no surprise that fusion yields of about 1/8 of joule of energy are no higher than the best results observed with copper electrodes.

While it is much too soon to say for sure why impurities have not fallen further, one clue may be in the large amount of gas that has been released in the early shots. This gas, mainly oxygen, shows up as a pressure "pop" after each shot, and has been observed before with newly installed copper electrodes. However, the amount of gas is more than three times larger than with the copper electrodes. It is thousands of times too much gas to be explained by adsorbed gas—oxygen adhering to the tungsten surface.

An alternative source might be a very thin layer of tungsten oxide—too thin to be seen or removed during the electrodes' cleaning. Tungsten oxide dissociates at 1970 C, far below tungsten's vaporization point of 5500 C, so an oxide layer will be far more fragile. The oxide layer might well give rise to the tungsten in the plasma as well. If this is the case, repeated firing will burn the oxide layer off and impurities will fall.

There are some hints that this may be happening, as x-ray emission and the pressure "pop" are falling as fusion yields are rising over the course of the first shots. But only more firing will confirm or refute this idea. The research team expects that as kinks are worked out of the system, firing will proceed more quickly, eventually reaching a goal of about 30 shots per week.

LPPFusion's 2015 Summer Research Associate- Clifton Whittaker

Clifton Whittaker, who will be a senior physics major at Whittier College in September has joined LPPFusion as a Research Associate for the summer of 2015. Whittaker has already contributed ably to helping fire the first shots with the new electrodes and troubleshooting early oscilloscope problems.

Clifton Whittaker – Research Associate