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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
August 15, 2016

Summary:

- **FF-1 puts 15 kJ into Pinch, Needs Help for Even More**
- **Preparations Advance for Next Round of Tungsten Experiments**
- **Safety Procedures, Instrument Design Paves Way for Beryllium Anode**

FF-1 Shots Put 12 kJ into Pinch Region, Needs 3D Modeling Help to Go Higher

A new analysis of LPPFusion's experimental results with the FF-1 device shows that fully 20% of the input energy was concentrated into the pinch region, where fusion reactions occur. As much as 12 kJ out of the capacitor bank's initial 60 kJ was compressed into the pinch. These results, obtained in June with tungsten electrodes and pre-ionization, are about twice as good as the best ones obtained earlier with copper electrodes. The analysis was based on the device's measured current and the voltage measured across the electrodes.

The significance of this result is that it implies that with higher current, nearly all the available energy can be transferred to the pinch. The energy available in the pinch is proportional to the square of the current, so with a current of around 2.8 MA, instead of the present 1.1 MA, energy into the pinch could be increased to 80 kJ, which is almost 70% of the maximum energy that can be put into FF-1. While a high efficiency of energy transfer into the pinch does not guarantee net fusion energy output (high density is also required, in addition to the high temperatures FF-1 already achieves), it is necessary for the net fusion goal.

How can FF-1's current be increased? One step is relatively easy—the LPP Fusion research team can put back into use the full 12 capacitors of the device, up from the presently-used 8 capacitors. (The team has put off doing this for now, because this puts more stress on the components and allows fewer spares). Another step, shortening the electrodes, is already planned. Shorter electrodes have less inductance—a measure of how much magnetic field energy is created for a given amount of current. Less inductance means more current for the same amount of stored energy.

But to get to the full planned current of 2.8 MA, the inductance of other parts of the FF-1 circuit must be reduced, so more energy is available inside the vacuum chamber, and less is wasted in magnetic field energy outside the chamber. The research team has some concrete ideas of how to do this, but we need help in testing them out. **LPPFusion needs paid help from someone who has done 3D modeling of pulsed power circuits and has present access to the software required—such as COMSOL. If you have these specialized skills, or**

know someone who does, please get in touch with us and we can give you more details and solicit a proposal.

Preparations Advance for Next Round of Tungsten Experiments

For the past month, the research team has been preparing for a second and final series of experiments with the two tungsten electrodes, before moving on to the planned combination of tungsten cathode and beryllium anode later in the fall (see next story). In the course of these preparations, we've come across a possible route to removing the tungsten oxides layers that have increased impurities in the plasma. Work by Alenka Vesel and colleagues at the Jožef Stefan Institute, Ljubljana, Slovenia showed that simple microwaves can remove the oxides. The microwaves heat a hydrogen fill gas to 900 C allowing the hot hydrogen atoms to react chemically with the oxygen in the tungsten oxide, forming water vapor. As the reaction occurs, over the course of 10 seconds, the water vapor can be pumped out, preventing the oxides from re-forming when the gas cools.

LPP Fusion Chief Scientist Eric Lerner is not certain this method will work as the microwaves will not be evenly distributed in FF-1 vacuum chamber, so uneven heating may lead to uneven oxide removal. "In your microwave oven, which is heated by the same device, a magnetron, that we'll be using, heating is evened out by a rotating turntable. But we don't have that in FF-1's vacuum chamber," he explained. But the new method is certainly worth a try and will be tested in September.

In the meantime, the team has been upgrading the instrumentation used to record and understand FF-1's operation. The fast ICCD camera has been out of action during the recent experiments. This turns out to be due to excessive radio-frequency noise that has affected the triggering of the camera and the transmission of images over a USB cable. To address this issue, Research Physicist Syed Hassan has installed a new wave generator to trigger the camera, and installed isolating transformers which remove noise from the power supplies to both the wave generator and the ICCD itself. In addition, the team has replaced the standard USB cable from the ICCD with a fiber-optic link and upgraded the shielding on the USB cables connecting the fiber-optic converter to the computer that records the images, which is located outside the experimental room. Finally, new optics are being installed to allow the ICCD camera to image the region where the discharge starts, on the anode near the insulator. This will allow the team to determine how well pre-ionization has reduced the vaporization of the anode material, another source of impurity.

A second upgrade involves a thorough calibration of the sensitivity and wavelength accuracy of the optical and UV spectrometer. This calibration will allow the research team, with the help of outside experts, to determine quantitatively how much tungsten and oxygen is in the plasma.

Finally, Electrical Engineer Fred van Roessel and System Administrator Jose Varela, working with Chief Information Officer Ivy Karamitsos are improving the data processing that analyzes the data from the photomultiplier tubes (PMTs) that measure x-rays from the experiment.

Safety Procedures, Instrument Design Paves Way for Beryllium Anode

The next step beyond the new experiments with the existing tungsten electrodes is the installation of the beryllium anode, expected to arrive in September. This will be the first time that a beryllium electrode has been used in any plasma focus device, an idea covered by LPPFusion's patents. While most work is still concentrated on the all-tungsten experiments, the LPP Fusion research team is also getting ready for beryllium. As a light metal, with only 4 electric charges per atom, beryllium will produce hundreds of times less impurity impact on the plasma than tungsten does, for equal energy inputs.

Beryllium metal by itself is harmless, but unfortunately beryllium dust is highly toxic to many people. So the first task was consulting with beryllium experts to find out the safest methods for handling even the tiny amounts of beryllium dust that may be produced by firing FF-1 with a beryllium anode. The good news is that beryllium dust will only be produced within the sealed vacuum chamber, where the dust can be safely flushed out with nitrogen. The dust will be trapped in HEPA filters, which will eventually be safely disposed of with local hazardous waste firms. To be doubly sure, we will probably install a sampling chamber so that a sample of the gas in the chamber can be checked at a local lab for dust before the chamber is opened.

In addition, the team is in the final stages of designing a small upper vacuum chamber that will be used to measure the electron beam produced by FF-1. The beryllium anode will have a central hole drilled all the way through to allow the electron beam to escape. In the upper chamber, the beam will be diverted by a magnetic field, allowing the distribution of electron energies to be measured. Care is being devoted to making sure that the electrodes themselves are adequately shielded against the magnetic field, which can introduce asymmetries in the formation of current sheath within the device.