Lawrenceville Plasma Physics, Inc

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

LPP Focus Fusion Report

February 28, 2014

Summary:

- **Tungsten electrodes in production: Cathode blank shipped, anode re-designed**
- **Crowdfunding plans advance with 60 volunteers – March 9 livestream event!**
- **Russian DPF gets 30 J with DT fuel, beats NIF gain ratio**
- **LPP-PPRC collaboration on pre-ionization experiments**
- **Data analysis confirms insulator safety, looks at x-rays**
- **New videos!**
    - **Cosmic connection: LPP's Lerner on Einstein and Black Holes**
    - **Fall 2013 Focus Fusion Cleantech NYC talk now available**

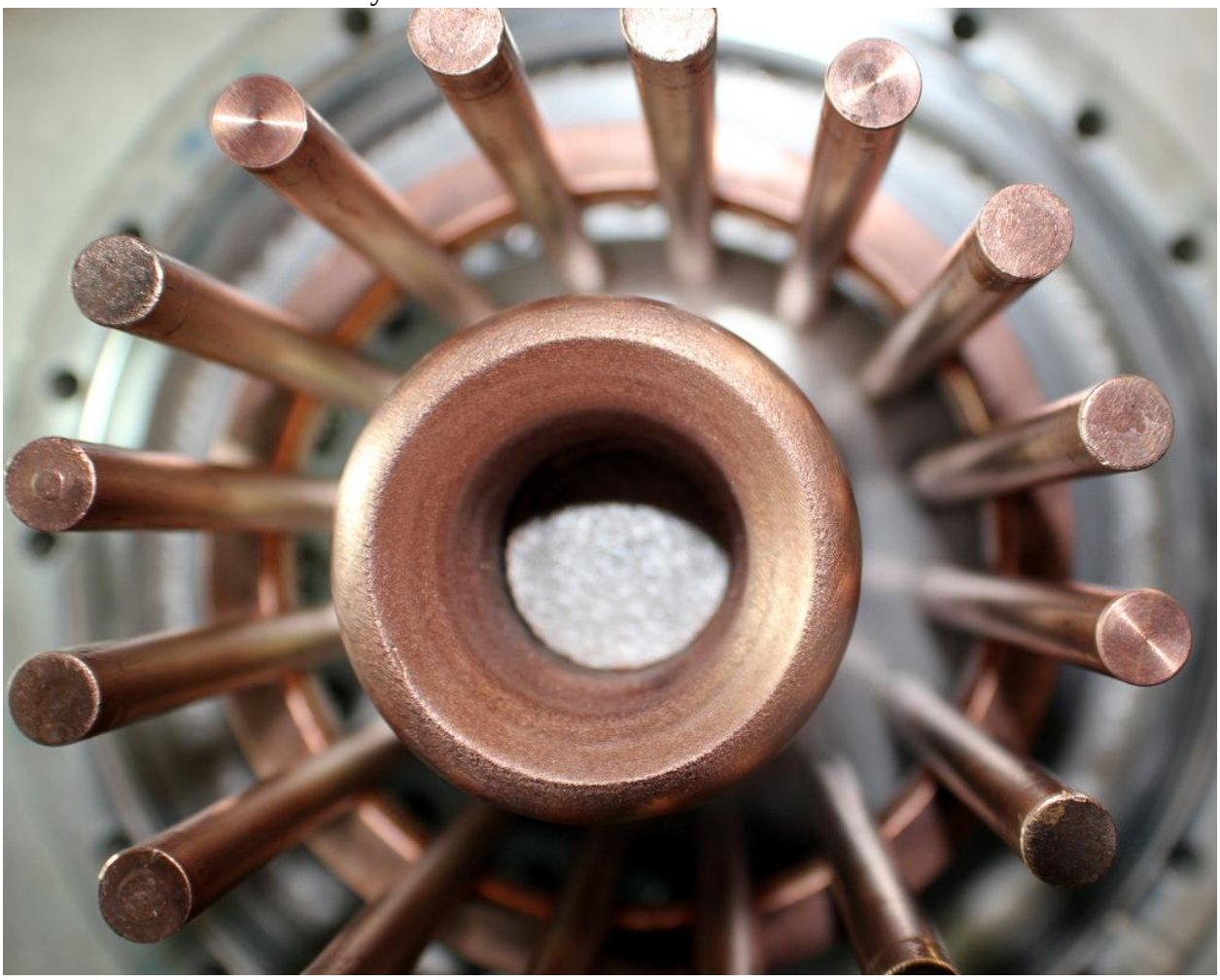
Tungsten electrodes are on their way with improved anode design

The tungsten electrodes needed for LPP's next set of experiments are rolling forward. The electrodes are needed to eliminate impurities, and cleaner plasma is expected to raise density and yield in the tiny plasmoids where fusion reactions take place. They are on track to be installed by mid-May. The tungsten blank for the cathode (the larger outer electrode) has been completed by Tungsten Heavy Powder and is being shipped to New Jersey. There another company, New Jersey Precision Technology, will machine the block into the exact shape required, a complex process expected to take about 10 weeks.

The tungsten blank, with outer diameter of 12" and total weight approaching 200 lbs, is prepped for shipping from San Diego.

In the meantime, LPP's research team decided that the tungsten anode needed an improved design. Calculations by Chief Scientist Eric Lerner indicated that the highest current anticipated with FF-1 will be 2.8 Mega-Amperes, about twice the highest yet achieved. Lerner's calculations showed this high current could cause arcing at the joint between the anode and its steel base. So the

anode was redesigned into a plate-and-cylinder combination shape so that the anode, like the cathode, will connect to the rest of the circuit outside the vacuum chamber. Not only will this design eliminate any possibility of plasma impurities from arcing, but by spreading the current at the join out into a larger diameter, it will eliminate any arcing at all, even at the highest currents. LPP Consultant John Thompson and LPP Board of Advisors member Rudy Frisch helped with the anode design and the corresponding design of a "ring of steel" that will apply even pressure to the anode connection, ensuring no arcing. With the re-design, the anode, too, is now being manufactured in time for May installation.



FoFu's current electrodes, with the inner cylinder of the anode surrounded by the 16 separate rods of the cathode. These multiple cathode parts will be united in one.

Crowdfunding Plans Move Forward as 60 Volunteer – March 9 livestream event!

As LPP, in cooperation with the Focus Fusion Society, moves forward toward launching its first crowdfunding drive, over 60 volunteers have come forward to help by signing up at LPP's website. In crowdfunding, contributions are solicited on central websites, such as Kickstarter or Indiegogo. The volunteers, from fifteen countries, have started to publicize the crowdfunding effort and have themselves pledged over $12,000. In addition, volunteers are starting to take on other tasks, such as selecting the best photos to upload to LPP's new website, planned to go live in late March.

On March 9, LPP will host our first crowdfunding "meet-up" in New York City, from 2PM to 4PM Eastern at Tekserve on 119 West 23rd Street. For those unable to attend in person, the event will be livestreamed via Google+ Hangouts on Air, from LPP's new Youtube channel.

The initial crowdfunding effort is planned to kick off on Earth Day, April 22. It will aim to raise the money needed for the project's most expensive set of equipment—the beryllium electrodes that will replace the tungsten electrodes now in the works. Beryllium will be needed for the final part of the research drive to demonstrate scientific feasibility because of the intense x-rays that will be generated as FF-1 approaches its highest performance. The x-rays are absorbed in a tiny layer of tungsten, and will vaporize it. But beryllium will be transparent to most x-rays and will spread out the rest harmlessly. However, beryllium is far more expensive than tungsten and the electrodes will cost as much as $250,000, something crowdfunding can supply.

In the run-up to the crowdfunding, LPP needs publicity and it got some when LPP investor Peter Arneson posted a well-written description of the project on the Contrarian Investor website. The lively discussion about the post was continued at the Tesla Motors website. The discussion increased traffic on LPP's website and motivated a wave of inquires about investments.

Plasma focus research moves forward as Russian device hits 30 J with deuterium-tritium

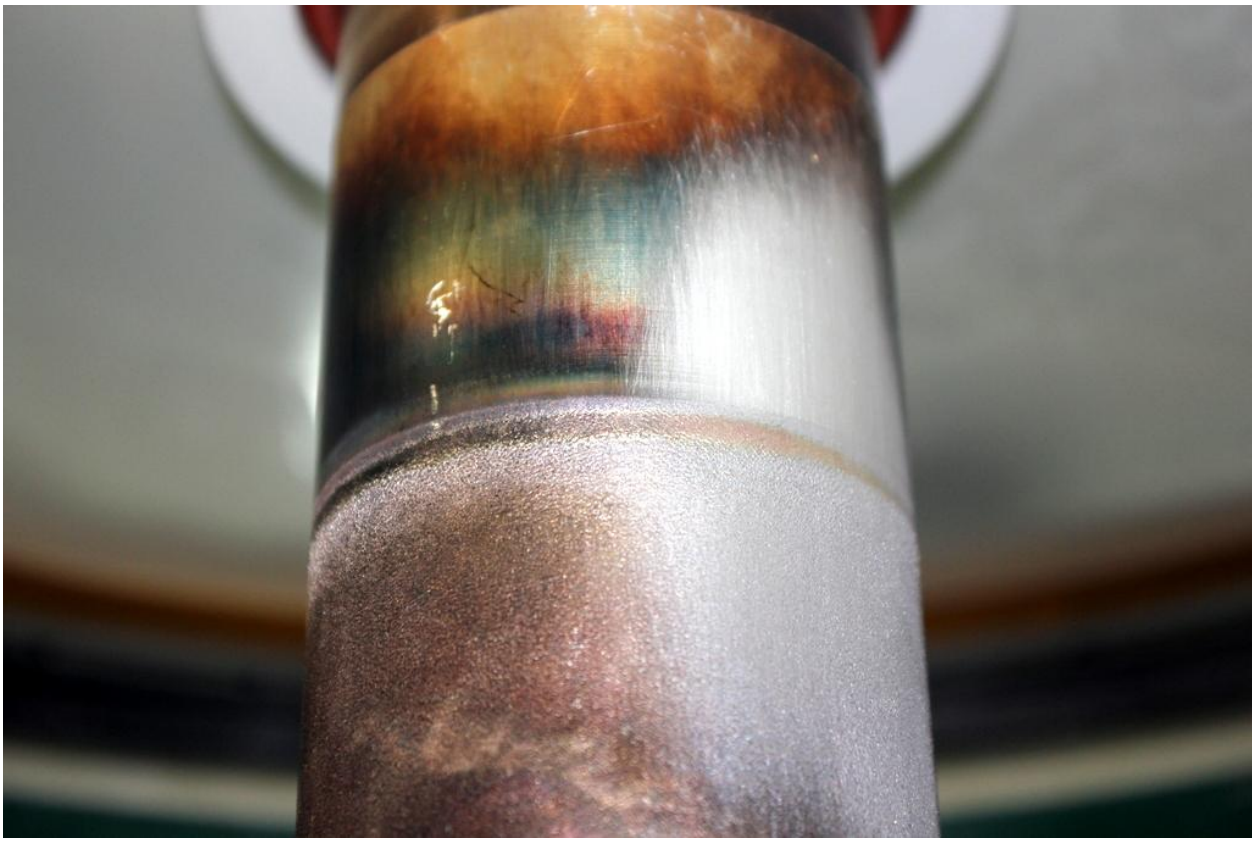
Many news outlets widely—and inaccurately—reported new results from the huge National Ignition Facility (NIF) as achieving the long sought-after goal of breakeven for fusion. What NIF in fact reported was a fusion yield of 17 kJ, more than the energy actually absorbed by the fuel pellet. The total input energy to the machine was far larger—some 500 MJ, so that 1 J of fusion was produced for each 30,000 J of input. This was indeed a big step upwards for NIF researchers but far from breakeven.

Meanwhile, science news reporters overlooked a major accomplishment in fusion a year ago by Russian researchers using a plasma focus device. These researchers performed their work at the Russian Federal Nuclear Center, All Russian Scientific Research Institute of Experimental Physics, in Sarov. They reported fusion yields of 30 J (1.3 x 10^13 neutrons) with the same deuterium-tritium fuel used by NIF. Since the total energy fed into the capacitors was 135 kJ, the Sarov team achieved a fusion yield of 1 J per 4,500 J of input, more than **six** times better than the NIF results. (The record for any DT fusion experiment is the JET tokamak in the UK, which in 1997 produced 1 J of energy per 450 J of input.)

While LPP's FF-1 device is not intended for use with DT fuel, it is useful to compare our results with those of the Sarov machine when using pure deuterium, a far less reactive fuel. With pure deuterium (D), Sarov produced 1 J of output per 2.2 MJ of input. FF-1's best results are 1 J of output per 400 kJ of input, about four times better. (The best results for any plasma focus using pure D are around 1 J for 100kJ of input, about the same as the best results ever obtained for tokamaks using the same fuel.)

LPP and PPRC collaborate on pre-ionization experiments

LPP's research team, having identified impurities vaporized from the electrodes as the main obstacle to higher yields, has been attempting to account theoretically for all sources of vaporization, so as to eliminate them. In January, the team looked more closely at the material eroded from around the anode near the insulator (see photo). Two things seemed surprising: the amount of material—about 1 mg per shot, or half of all the impurities in the plasma; and the fact that the vaporization occurred right at the start of the pulse, when the current flow is the weakest. No possible mechanism seemed to account for so much erosion so fast.



The FF-1 anode, which is plated with 0.001 inches of silver, shows a ring of erosion near the end of the insulator (which has been removed along with the cathode). On the right side, where deposits have been cleaned away, the copper color shows clearly where a ring of silver has been vaporized and measurements show about 0.12 grams eroded in 125 shots. On the left side, not cleaned, the copper is deposited lower on the anode, covering up silver below.

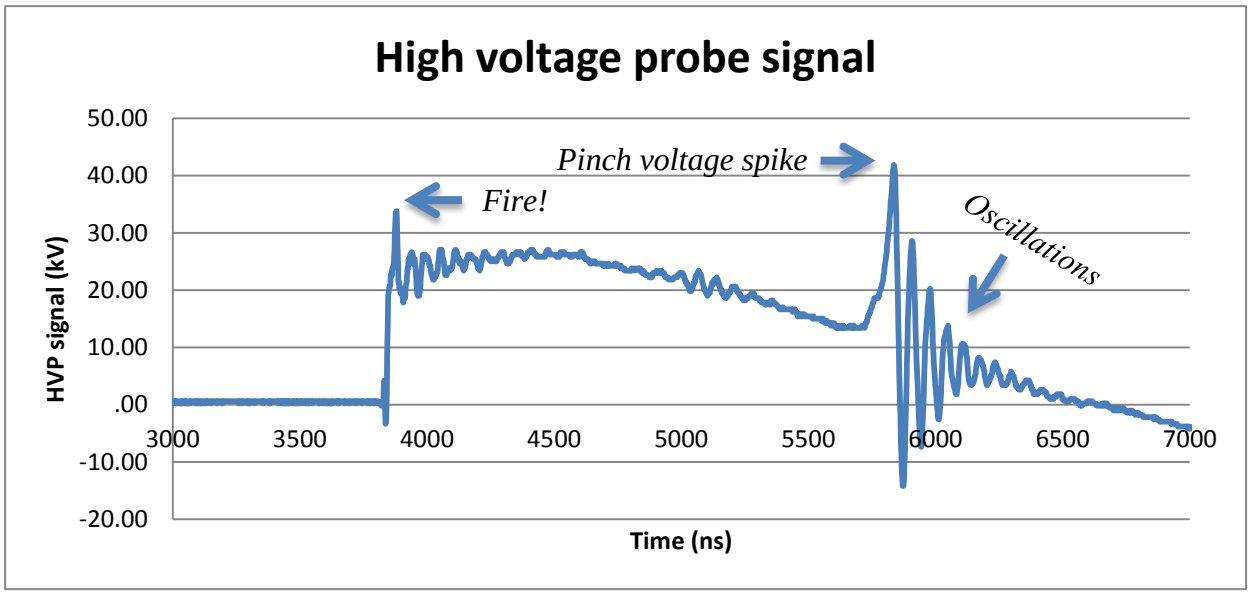
A literature search turned up the answer: runaway electrons. Runaway electrons occur when very strong electric fields, such as in lightning bolts, accelerate electrons moving through a mainly neutral gas. If the field is strong enough the electrons gain more energy from each collision with an atom than they lose in the collision, thus speeding up to high energy. In FF-1, electrons gains as much as 3 keV of energy, slamming into the anode and depositing enough heat energy to vaporize the silver plating and some of the copper underneath. Once the plasma is fully ionized and its resistance drops, the high accelerating fields no longer exist, so the runaway electrons stop—But by then, the plasma has already been contaminated.

There are two solutions to this problem. One is simply increasing the initial pressure of the gas, so more collisions occur. This will happen with FF-1 as it approaches peak current. But for now, an additional solution is needed: pre-ionization. In this technique a small current breaks down the plasma resistance before the main pulse passes through—smoothing the way, as it were. The small pulse has too little energy to cause runaway electrons, and by the time the main pulse comes through, the resistance that can sustain the large electric field is gone. Experiments by plasma focus groups in Pakistan and elsewhere had good results with pre-ionization.

To directly test if pre-ionization can eliminate the "ring around the anode" erosion, LPP's collaborators at the Plasma Physics Research Center (PPRC) in Tehran, Iran are conducting experiments using this technique on their 2-kJ DPF device. At the same time, LPP is doing preliminary tests of pre-ionization techniques on FF-1. Together, the experiments should be able to show how to eliminate this source of erosion prior to FF-1's next round of experiments with tungsten electrodes.

Digging in the Data—oscillations and x-rays

The months that FF-1 is not running have given the LPP research team time to look more deeply at the hundreds of gigabytes of data that the experiments have been generating. One puzzle LPP Electrical Engineer Fred van Roessel looked at was the rapid oscillation in current and voltage that occurs when the machine fires and right after the pinch (see graph). These are almost always seen in plasma focus devices but have not had a satisfactory explanation. Van Roessel wrote programs to analyze the oscillations, concluding that they were due to current sloshing back and forth along the transmission plates that connect the capacitors to the electrodes. This hypothesis implied that the peak voltage the device generates during the pinch is proportional to the total drop in current at the same time. Sure enough, the data for the past year showed that the ratio of the voltage spike at the time of the pinch relative to the drop in current during the pinch is constant at 72 milliohms with a standard deviation of only 16%.



The above graph points out key features of the high voltage probe signal.

This result is important because it allows us to predict that the maximum possible voltage spike is 200 kV, well below the 1 MV estimated strength of the main Mylar insulators. It is even further below the 5 MV strength of the ceramic insulator that separates the electrodes.

In addition, we now have some part-time help with the data analysis—our new high school intern, Matthew Ho. Matt has been working with Van Roessel and Lerner to analyze the x-ray data which will give insight into the electrons in the plasmoid. Some tantalizing clues have already turned up. Stay tuned!

Cosmic connection—Lerner sets the record straight on Einstein and Black Holes

In a response to Stephen Hawking's recent paper on the non-existence of black holes, LPP Chief Scientist Eric Lerner produced a video explanation of how Einstein proved in 1939 that his general relativity theory proved black holes do NOT exist. The myth that relativity predicted black holes arose in the 1960's after Einstein's death. It originated among researchers studying quasars, vast explosions in space. Lerner's research on how electromagnetic forces could explain much about quasars used the plasmoids produced in the dense plasma focus device as a model of the quasar process. This study in the 1980's laid the theoretical foundations for LPP's Focus Fusion research. Watch the full video here.

Fall 2013 Focus Fusion Cleantech NYC talk now available

In other video news, LPP has launched our own YouTube channel, separate from the Focus Fusion Society's still valued presence at http://www.youtube.com/FocusFusionSociety and linked to our Google+ Page. The new channel's first video is a recording of a talk by Eric at the NYC Cleantech Opportunities event in November 2013. Share it or other videos to introduce Focus Fusion to your network!