Lawrenceville Plasma Physics, Inc

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

Focus Fusion Report

January 31, 2012

Summary:

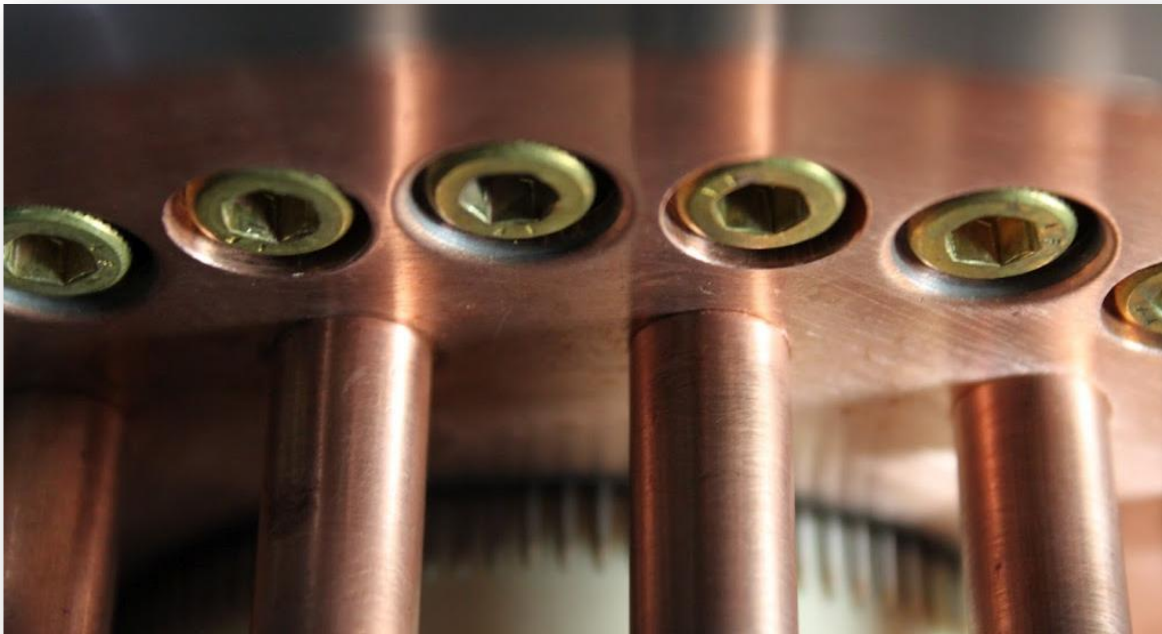
- **Arcing identified as obstacle to higher yields, fixes to be tested next month**
- **New analysis of energy production in FF generator**
- **Looking back and forward—achievements of 2011 and goals for 2012**

Arcing identified as key problem, cures will be tested in early February

LPP's research team observed a recurrence of arcing problems within FF-1's cathode and between the cathode and the steel plate it is attached to. Arcing occurs when the contact between two metal pieces is insufficiently close and current jumps through the gap, creating a spark. In this situation, electrons accelerate to the point that they can vaporize copper or steel. This vapor can then enter the plasma unevenly, creating asymmetries that interfere with the even compression of the plasma and thus reduce fusion yield. The team observed that arcing was occurring between the copper cathode rods and the copper cathode plate they are screwed into and, more extensively, between the copper plate and the steel buss plate from which it receives current.

After testing and eliminating various causes for the arcing, we concluded that the main problem was insufficient pressure applied to the electrical contacts. For the copper plate, we have added 16 more brass bolts to double the pressure, and smoothed the contact surfaces, while for the copper rods, we have added thin copper washers where needed to make a tighter fit.

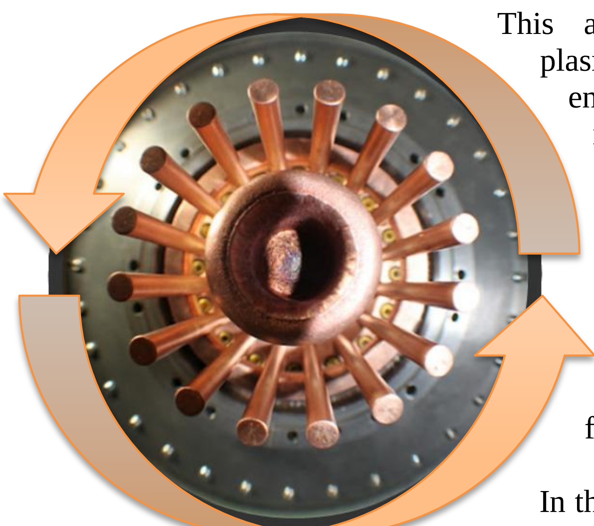
Unfortunately, our test of the new fixes was delayed when an error in the assembly of the electrodes led to the breaking of the ceramic insulator that separates the cathode and anode. We do expect to accomplish the test in the first half of February, and expect higher fusion yields to result.



Double the bolts, double the electrical contact pressure!

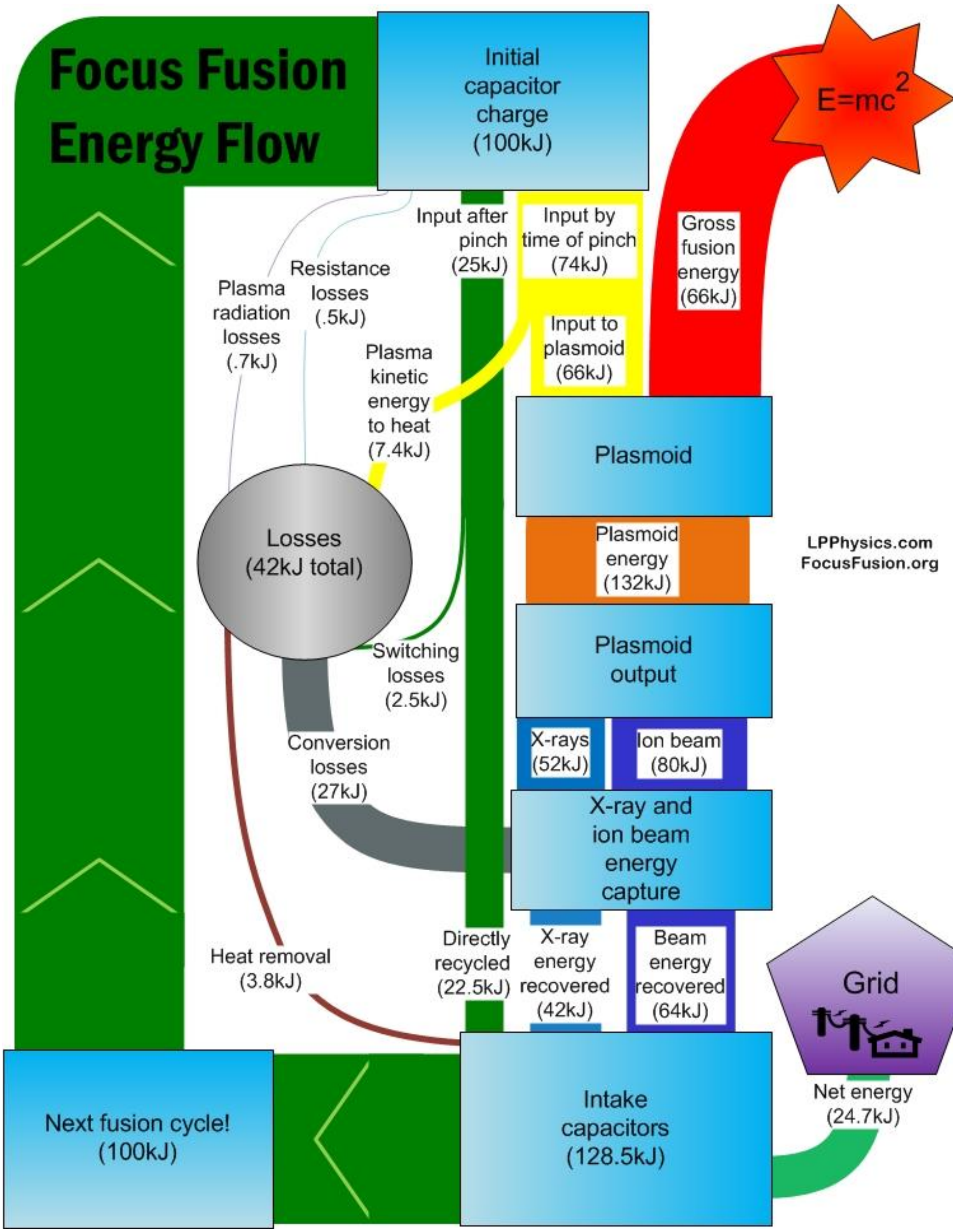
Energy flow of FF generator updated

In response to questions about the energy balance and energy flow in a Focus Fusion generator, LPP has updated our analysis based on our most recent data and calculations. The result is summarized in a chart called a Sankey diagram, in which the width of connecting lines represents the amount of energy. We want to emphasize that at this point in the research, there are large uncertainties in any net energy analysis, but it is important to illustrate what is meant by "net energy" from a Focus Fusion generator.



This analysis assumes 90% energy transfer to plasmoid, a ratio of fusion energy to plasmoid energy ratio of 100%, 80% energy efficiency recovery from the beam and X-ray pulse. If energy-recovery efficiency is only 70%, net energy is reduced to 14.6 kJ, but is still positive. If fusion energy is 120% of plasmoid energy instead of 100%, net energy yield is increased to 35 kJ. Net energy production occurs if gross fusion energy is above 35 kJ, the goal of our scientific feasibility demonstration.

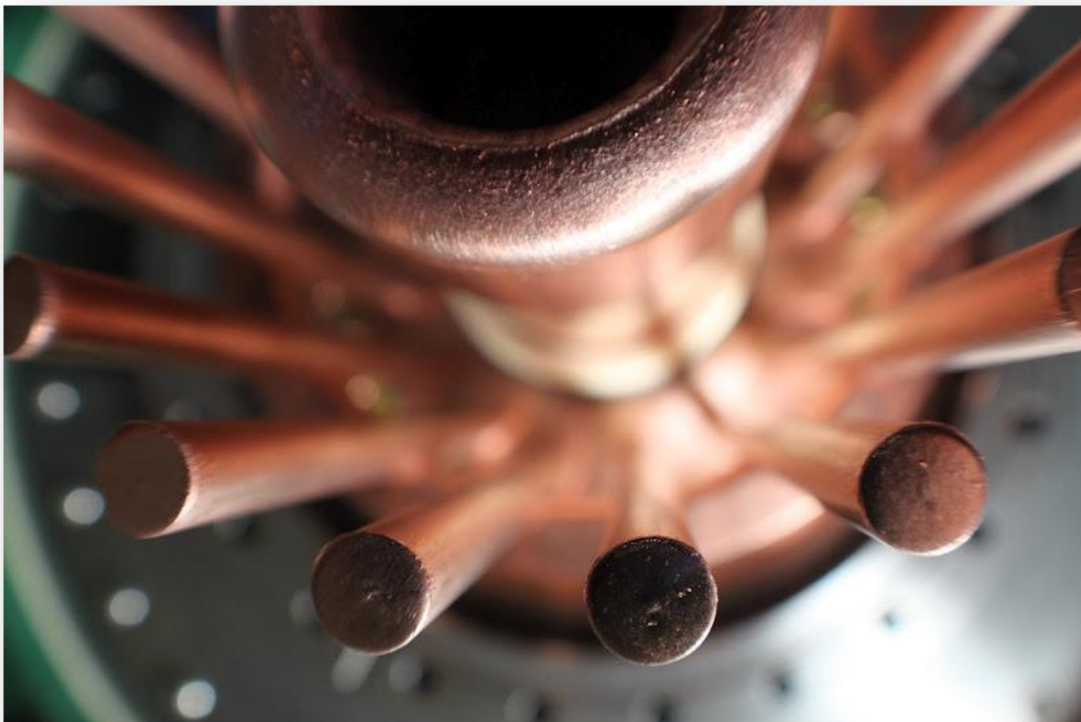
In the baseline scenario of the diagram, cycling 200 times per second would provide 5MW to the grid.


Focus Fusion Energy Flow
Initial capacitor charge (100kJ)
E=mc2
Input after pinch (25kJ)
Input by time of pinch (74kJ)
Gross fusion energy (66kJ)
Resistance losses (.5kJ)
Plasma radiation losses (.7kJ)
Input to plasmoid (66kJ)
Plasma kinetic energy to heat (7.4kJ)
Plasmoid
Losses (42kJ total)
Plasmoid energy (132kJ)
LPPhysics.com
FocusFusion.org
Plasmoid output
Switching losses (2.5kJ)
Conversion losses (27kJ)
X-rays (52kJ)
Ion beam (80kJ)
X-ray and ion beam energy capture
Heat removal (3.8kJ)
Directly recycled (22.5kJ)
X-ray energy recovered (42kJ)
Beam energy recovered (64kJ)
Grid
Net energy (24.7kJ)
Next fusion cycle! (100kJ)
Intake capacitors (128.5kJ)

Looking back, looking forward

A year ago, LPP released a detailed year-end report on our research. Feedback from that report indicated that most readers thought it was much too detailed. So this year we are simply highlighting the main developments of the past year, and the next steps we intend to take in completing the research phase in 2012.

To review, in 2010 we achieved two key goals—confirming the generation of ion energies of over 100 keV (one billion degrees) and increasing the efficiency of energy transfer into the plasmoid to more than 10% of the total bank energy.



In 2011, the key scientific achievements of our project were:

1) Demonstrating the continuation of I^5 power scaling of the fusion yield—that is, showing that fusion energy per shot continues to increase with the fifth power of the peak current, as predicted by our theory.
2) Record (for FF-1) fusion yield of 150 billion neutrons.
3) Improvement of repeatability of fusion yield 1st to within 15%, then to within 3%.
4) Fusion yield at the highest pressures (over 40 torr) for any dense plasma focus device.
5) Demonstrating the technical feasibility of the X-scan spin-off inspection technology by showing high X-ray transmission through 6 inches of metal.

These achievements were made possible by several technical advances:

1) Synchronous and reliable operation of the new switch design deployed August 2011.
2) Reliable functioning of FF-1 above 40 kV and initial shots at 45 kV (full voltage).
3) Improvement in the symmetry of the electrodes.

In addition, we published our basic theory and preliminary results in a peer-reviewed journal, the Journal of Fusion Energy, with two additional publications under review.

While we have made significant progress, we did not move forward as quickly as we had planned. The basic reasons for this are the time it has taken to resolve some of the key engineering issues, such as the switches, and the small size of our staff, ultimately imposed by LPP's finances. If we look at our progress as measured by number of shots, instead of by number of months, our research has been progressing about as planned. We originally calculated that we would need 2,000-2,500 shots to complete the research program from where we were in January 2011. During 2011, we only fired FF-1 600 times, due to the time needed for various technical upgrades, and our progress was actually greater than we had anticipated for that number of shots.

Looking forward, we expect in the coming year to achieve the following major goals:

1) Demonstrating the theoretically predicted fusion yield with pure deuterium.
2) Showing higher fusion yield with heavier gas mixtures.
3) Achieving reliable performance at still higher fill pressures.
4) Boosting yield even further with shorter electrodes, which allow higher gas densities.
5) Achieving giga-gauss magnetic fields in the plasmoids.
6) Demonstrating the quantum magnetic field effect's reduction in X-ray cooling
7) Demonstrating scientific feasibility with pB11 fuel.

Achieving these goals depends on further upgrades to FF-1, including an even faster set of switches under design by a leading commercial supplier (more on that in the next report) and, critically, obtaining funds to hire at least two more full-time staff.

The interior of FF-1's anode, etched by the electron beams of hundreds of fusion shots… with many more on the way!