



Lawrenceville Plasma Physics, Inc

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

## 2012 End-of-Year Report

January 3, 2013

### 2012 Summary:

- LPP published in a leading peer-reviewed journal, *Physics of Plasmas*, our achievement of two out of the three conditions needed to produce net energy: a record-high temperature and the required confinement time of the hot plasma.
- LPP demonstrated that our approach is, by far, the leader in the effort to achieve aneutronic, radioactive-waste-free, fusion—the only known route to clean, cheap, safe, and unlimited energy.
- LPP eliminated arcing problems in the FF-1 fusion device that were blocking progress; it developed and used simulations to improve the FF-1 fusion device design, and acquired a greater theoretical understanding of FF-1's 1.8 billion-degree temperatures.

### In 2013:

**If \$1.5 million in financing is raised in January, we expect to achieve proof of scientific feasibility (more energy out than in) in 2013, but only with such timely funding.**

Our main achievement in 2012 was to demonstrate, as described in our [publication in \*Physics of Plasmas\*](#), the world's leading plasma physics journal, that we had achieved the sufficiently high temperature of 1.8 billion °C and the sufficient confinement time of tens of nanoseconds necessary to produce net energy from hydrogen-boron fusion. This means that we have achieved two of the three conditions needed for net energy—the third being sufficient density of the plasma.

Through this publication, and through papers presented by us and others at the October American Physical Society Plasma Physics conference, it was demonstrated that our approach is far ahead of the two competing methods for achieving aneutronic, or radioactive-waste-free, fusion. (See detailed comparison in the appendix.) **Our results are 100 times better than the best achieved by the inertial electrostatic confinement device (pioneered by EMC2) and 30,000 times better than those of Tri Alpha Energy.** Since aneutronic fusion is the only known means that could produce safe, nonpolluting, and unlimited energy at a cost well below that of existing technology, this comparison means that LPP is the most advanced effort on the route to this crucial goal.

Despite having only one-quarter of the money available to us that we had deemed necessary at the beginning of 2012, we made significant progress in our experimental and theoretical work. We eliminated arcing (electrical leaks) within the FF-1 fusion device and collected extremely useful data, thanks to the outstanding work of LPP Laboratory Coordinator Derek Shannon and Electrical Engineer Fred Van Roessel. Simulations performed by Dr. Warwick Dumas and Dr. John Guillory led us to refine our electrode design. Theoretical work by visiting researcher Ahmed Talaei and LPP Chief Scientist Eric Lerner led to a better understanding of how we achieved the extremely high temperatures that we have, and how to go to even higher temperatures.

In addition, we initiated collaboration with the Plasma Physics Research Center in Iran, established closer collegial links with Princeton Plasma Physics Laboratory, and set up collaboration with Japanese simulation scientists. These collaborations will help substantially in accomplishing our goals in 2013.

However, at the beginning of last year, we reported that achieving our goals in 2012 depended on having funds for at least two more full-time physicists and for significant upgrades to FF-1, including a faster set of switches. Since that funding, \$2 million, was not available last year, we had neither the manpower nor the equipment to achieve the 2012 goals. Directly because of these limitations, we were able to fire FF-1 only 250 times instead of the 1,500-2,000 shots we predicted would be needed to achieve scientific feasibility—proof that an experimental device can produce more energy out than is put in.

Our experiments so far indicate no new obstacles to achieving scientific feasibility, once the FF-1 device is functioning as designed. What remains to be done, and what we remain confident can be accomplished in 2013, is to:

- 1. Achieve the third condition for net energy—sufficient plasma density in the plasmoid (the tiny ball of plasma created by the device)—by:**
  - **Improving the symmetry of the current sheath to bring the density from our current *0.1 milligrams/cm<sup>3</sup>* to our theoretically-predicted level for pure deuterium which is *tens of milligrams/cm<sup>3</sup>*;**
  - **Continuing the density increase by mixing in nitrogen, krypton and other gases, with the density at this stage reaching *hundreds of milligrams/cm<sup>3</sup>*;**
  - **Shortening the electrodes, which will lead to the ultimate plasma density needed to achieve the fusion net-energy production, a density of the order of *grams/cm<sup>3</sup>*.**
- 2. Achieve billion-gauss magnetic fields in the plasmoids needed for the quantum magnetic field effect.**
- 3. Demonstrate the quantum magnetic field effect within these billion-gauss magnetic conditions; show its ability to prevent plasmoid cooling caused by X-rays, making possible the net energy burning of pB11 fuel.**
- 4. Demonstrate scientific feasibility with pB11 fuel: more energy out than in.**

These goals can be reached in 2013 *only* if the remaining funding, which we estimate at \$1.5 million, is available this January, enabling us to hire at least two more highly qualified and experienced researchers, to buy the required equipment and to cover our operational costs.

The next phase of our project, once the above goals are achieved, will be the engineering and development of a working 5 MW prototype fusion electric generator, followed by the licensing and mass production phase. We estimate it will take about three more years after 2013 and \$50 million for the engineering and development phase, assuming timely funding.

Also during 2012, we have taken steps to increase LPP's ability to raise the needed funds. We have improved our intellectual property by gaining a **patent in China**, our third after the United States and Australia. We have increased our visibility with press coverage in the [Guardian](#), [Forbes](#) and [RT television](#). Equally important, we have started, thanks especially to the efforts of LPP Chief Information Officer Ivana Karamitsos, to explain our work more [clearly](#), through [web pages](#), [educational videos](#) and [vlogged public appearances](#). We believe these will help reach a wider audience of investors with non-technical backgrounds.

However, our scientific productivity has been slowed by the need for our enthusiastic but too-small staff to divert its time towards fund-raising. This constant double-tasking yields less than half the results in both our scientific research and our fund-raising. We hope this will end with sufficient funding in hand at the beginning of 2013. In that case, the coming year will be the year that we take a giant step towards an unlimited energy future.

#### **Appendix—comparison with other approaches:**

##### **Latest IEC results show large continuing lead by DPFs in fusion yield**

Currently there are three experimental approaches to aneutronic fusion with hydrogen-boron fuel (in addition to other conceptual approaches which have not yet reached the experimental stage.) They are the dense plasma focus device, used by LPP; Tri Alpha's field reversed configuration, discussed below, and inertial electrostatic confinement or IEC, used by EMC2's Polywell devices and by academic groups like that at the University of Wisconsin, Madison (UWM).

While the EMC2 effort has not published anything in recent years, UWM has been publishing and LPP Chief Scientist Lerner last month was able to get some updates on the field from Dr. John Santarius, one of the leaders of the UWM team. These updates showed that in terms of fusion output per unit of energy input, plasma focus devices still have a large lead over IEC devices. This of course does not mean that our Focus Fusion approach will necessarily win the race to net energy production, but it is a reflection of where things stand now.

Dr. Santarius reports that their best results with deuterium fuel are 20,000 neutrons per joule of energy input. By comparison, FF-1's best results with the same fuel are 150 billion neutrons for 60,000 joules input, or 2.5 million neutrons per joule. **So, at the moment, plasma focus devices produce over 100 times more fusion energy per unit input energy than do IEC devices. (Not that our results are yet good enough. We are aiming for thousands of times better than we now get.)**

IEC devices operate by trapping ions within an electrostatic field. The field also accelerates them to high energy, so like DPF devices, they can get to the ion energies needed to burn hydrogen-boron fuel. However, at the moment, very little of the fusion energy in an IEC comes from hot ions colliding with hot ions, as it does in the DPF. Rather, the ions collide with the cold background gas. The problem with that, as IEC researchers are aware, is that the energy output only increases proportional to the energy input, not faster. Net energy then gets no closer with increasing input.

If, on the other hand, ions collide with ions, each ion encounters more collisions, so the energy output can increase as the square of the energy input or even faster, then net energy gets closer with more power input. For this to happen with IEC, experiments will have to develop better vacuums to reduce background collisions and, most difficult, there will have to be far fewer collisions of ions with the device structure itself.

While IEC is certainly worth researching, the comparison again confirms that research with the plasma focus is still the path closest to achieving net energy with aneutronic fusion—the only known route to cheap, clean, safe, and unlimited energy.

### **Comparison with Tri Alpha Energy**

Tri Alpha Energy, which is pursuing aneutronic fusion with a different device from the plasma focus, presented their past year's progress with a half-dozen poster presentations at the American Physical Society's Plasma Physics conference in October, 2012. The clear and thorough presentation of their results was due to a new openness by their management, according to several of the researchers participating. Tri Alpha's device, called a field reversed configuration, or FRC, generates two large rings of plasma and heats them with an externally accelerated ion beam. Their most recent results show that they have confined plasma at about 100 eV energy (equivalent to 1.1 million degrees C) for about 2 milliseconds at a density of  $2 \times 10^{13}$  ions/cm<sup>3</sup>.

While this temperature is too low to produce measurable fusion energy, a rough measure of overall progress is the product of these three numbers, called " $n\tau T$ ", which for Tri Alpha is  **$4 \times 10^{12}$  eVsec/cm<sup>3</sup>**. By comparison, LPP's FF-1 with an ion energy of 160 keV, confinement time of about 30 ns and density of  $3 \times 10^{19}$  ions/cm<sup>3</sup> has a  $n\tau T$  product of  **$1.4 \times 10^{17}$  eVsec/cm<sup>3</sup>**, a factor of about 30,000 larger than that of Tri Alpha. **This puts LPP far closer to the goal of net energy for now.** Tri Alpha has raised about \$140 million in private investments and works with a staff of 30 physicists. Considering that Tri Alpha has raised \$140 million with 30,000 times more modest results, we feel that this investment in LPP is a real bargain—the best buy in fusion.