Lawrenceville Plasma Physics, Inc.
ECO-CLEAN, SAFE, VIRTUALY INFINITE & AFFORDABLE ENERGY

LPP Focus Fusion Report

September 8, 2014

Summary:

- **Fusion Policy: *Nature* calls for funding aneutronic fusion; ARPA-E puts $30 million for fusion alternatives; *Science* covers fusion start-ups**
- **Dr. Hamid R. Yousefi is new LPP Chief Research Officer**
- **Assembly of FF-1 with tungsten electrodes begins**

Fusion Policy Shifts: Nature urges funding aneutronic fusion, LPP; ARPA-E puts $30 million to alternatives; *Science* covers fusion start-ups


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NATURE | EDITORIAL
عربي
Fusion furore
Soaring construction costs for ITER are jeopardizing alternative fusion projects.

In the past month, the long simmering debate over the direction of the international fusion effort has finally bubbled to the surface. In a July 23 editorial, *Nature* magazine, one of the leading scientific journals in the world, has joined the calls to redirect fusion funding to aneutronic fusion—fusion that produces no radioactive waste. Speaking of the difficulties facing the ITER tokamak program, the editorial urged that, "Given these realities, the prudent course for the world's funding agencies would be to support research into alternative fusion fuels, such as deuterium-helium-3, or proton-boron-11—which require higher temperatures to ignite, but produce very few neutrons—as well as alternative reactor designs that would be simpler, cheaper and more in line with the kind of plant that power companies might buy."

Nature specifically urged that one of the projects that should be considered for government funding be “Lawrenceville Plasma Physics in Middlesex, New Jersey, which is trying to exploit a configuration known as a dense plasma focus (DPF) to build an extremely compact reactor that does not emit neutrons.” LPP, now known as LPPFusion, Inc, was one of only two projects that the editorial cited as examples of worthy projects, the other being the University of Washington effort of Thomas Jarboe and his group. The editorial in *Nature* adds to the many voices that have advocated changing the direction of the international fusion program. Over 50 scientists have signed an open letter urging such a broadening of the fusion effort, especially to include aneutronic fuels. Less than a month later, in late August, The US Department of Energy’s Advanced Research Projects Agency-Energy (ARPA-E) announced a program that will put $30 million over a three year period into 12-15 fusion projects using alternative approaches. Long in the planning, the new program will fund efforts that “help enable a path to economical fusion power through low-cost, high shot rate development.” It will specifically be aimed at devices that produce plasma in an intermediate density range of 10^{18} to 10^{23} ions/cm^3, between the low densities of the tokomak and the very high ones of laser fusion.

While the ARPA-E program is a step in the right direction, toward a broad-based fusion program, it fails to mention in any way aneutronic fusion fuels. These are an essential part of the route to economical fusion, as the *Nature* editorial points out. Indeed, the requirements of the program include one that may be biased against aneutronic fuels. This is the requirement that fusion yield exceed input energy by a factor of 5. Such a requirement is needed for DT fuel that produces energy as heat and must be converted to electricity at low efficiency. But it makes no sense for aneutronic fuels that produce energy as charged particles that can be converted to electricity at efficiencies as high as 80%. Since aneutronic fuels burn at higher temperature than DT, they in fact need higher input energy—but more than compensate for this by high efficiency, low cost of conversion equipment and the total elimination of radioactive waste.

Nature was not the only leading journal to cover fusion alternatives in the last month. *Science*, another one of the leading science journals in the world, featured LPPFusion’s work on Focus Fusion in a news article in the July 25 issue on privately-funded alternative approaches to fusion. The article, titled “Fusion’s Restless Pioneers” also featured two other efforts aiming at aneutronic fusion, Tri-Alpha Corporation and EMC2, as well as General Fusion.

LPPFusion Names Dr. Hamid R. Yousefi as Chief Research Officer

Dr. Hamid R. Yousefi at his new desk at LPP's home office.

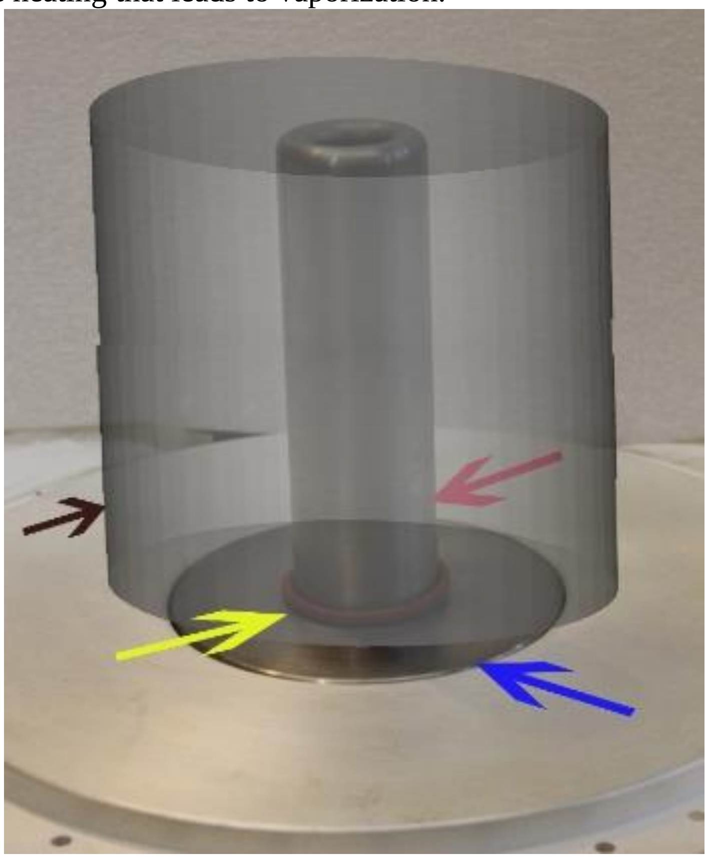
LPPFusion, Inc. has hired Dr. Hamid R. Yousefi as Chief Research Officer. Dr. Yousefi has been collaborating remotely with LPP Chief Scientist Eric Lerner for the past seven years on Focus Fusion research and was one of the first scientists outside LPP to realize the potential of this approach. He was the first to develop, with colleagues in Japan, a particle-in-cell simulation code for modeling some aspects of the fusion reactions of hydrogen-boron fuel. Through these simulations he was able to show a number of mechanisms for both the heating of the plasma to the high energy needed for fusion and the acceleration of intense ion beams which have long been observed in the plasma focus. This work resulted in several papers in leading journals, such as *Physics of Plasmas* and *Physics Letters A*. He also carried out experimental studies of some of the obstacles to optimal plasma focus functioning, such as impurities from the anode. His published work on the optimal length of insulators in the DPF was used in the design of LPP's FF-1 device. At the Plasma Physics Research Center (PPRC) in Iran, where he was an assistant professor, his efforts led to a number of new plasma focus facilities in Iran. He has participated actively in the collaboration for scientific publication between LPPFusion and the PPRC.

Dr. Yousefi is working in the United States, consistent with the US immigration and other legal requirements, under an O-1 visa, issued to scientists and other professionals who are outstanding in their fields.

As Chief Research Officer, Dr. Yousefi will assume principal responsibility for the experiments with FF-1, freeing Lerner for more work on the remaining theoretical problems of achieving practical fusion energy. "Of course we remain a small team, so I'll continue to collaborate on the experiments and Hamid will collaborate on theory, but having the full-time work of a plasma physicist of his extraordinary ability and commitment will immensely help our project," explains Lerner.

Re-Assembly Begins of FF-1 with Tungsten Electrode

The first steps have now been completed to begin the re-assembly of FF-1. LPP's lab team has successfully joined the new monolithic tungsten anode to a steel connector plate, creating a current contact that is outside the vacuum chamber and arcing-proof. Moving the contact outside the vacuum chamber completely eliminates the possibility that vaporization caused by arcing will add impurities to the plasma. In addition, making the contact at a lager radius spreads out the current, making it easier to avoid the intense heating that leads to vaporization.



The new tungsten anode has a current connection with the silvered steel plate at the edge indicated to by the blue arrow. This current connection is below the red O-ring (yellow arrow) that seals the vacuum chamber indicated by the black arrow. The old current connection was at the location of the red arrow, inside the vacuum chamber and at a small radius, where the concentrated current jumping from one piece of metal to the other could vaporize the anode material and contaminate the plasma.

But additional steps are still needed to be taken to make sure arcing would not occur even as FF-1 device increases its peak current. Arcing outside the chamber can't hurt the plasma but it can damage the Mylar sheets that insulate the anode plate from the ground plate below it, possibly causing insulator failure. So the LPP team plated this steel with silver and carefully squashed indium metal between the steel and the tungsten to insure low resistance.

Hours of painstaking indium application had finally paid off in the fight against arcing, resulting in the very low resistance of 6 micro -ohms between the silvered steel plate and the inner slightly raised plate in the middle.

Our student intern Taylor Smith from Canada helped improve techniques and with the work of CIO Ivy Karamitsos and Dr. Yousefi we succeeded in reducing resistance below 6 micro-ohms, three times better than our goal. Thanks also to consultant John Thompson and Board of Advisors member Rudy Fritsch for help and designing the anode connection. We will now mount the steel plate and anode onto the FF-1 device. We currently expect assembly to be complete in October.

Taylor and Hamid watch Eric put the steel pressure ring onto the anode assembly. The pressure ring was bolted in place to squeeze the tungsten and steel tightly together, minimizing resistance.