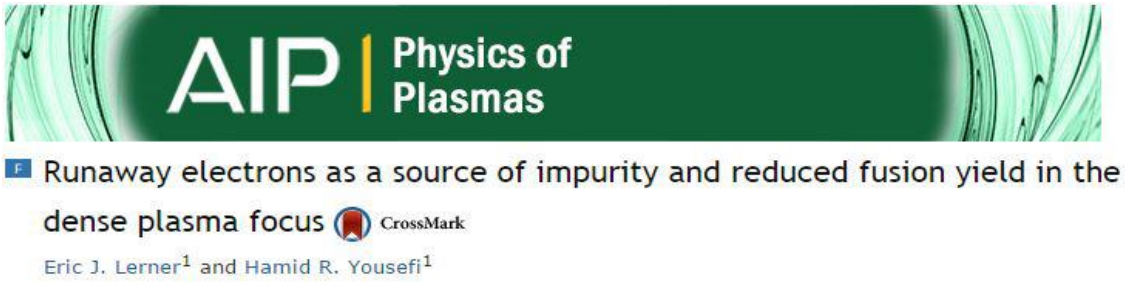
LPP Focus Fusion Report

November 17, 2014

Summary:

- ***Physics of Plasmas* Publishes LPPFusion Runaway Electron Theory**
- **LPP's Lerner Visits Sewanee, University of the South**

Physics of Plasmas Publishes LPPFusion's Runaway Electron Theory



Physics of Plasmas, the leading journal in the field of plasma physics, has published LPPFusion's new paper on "Runaway electrons as a source of impurity and reduced fusion yield in the dense plasma focus". The paper, by Chief Scientist Eric J. Lerner and Chief Research Officer Hamid R. Yousefi, was published online October 22, 2014 less than a month after it was submitted for peer-review. Physics of Plasmas had published a previous LPPFusion paper on record-breaking ion energies in 2012.

The new paper describes the evidence that runaway electrons are a key cause of vaporization of electrodes in the dense plasma focus device, an idea first reported on LPPFusion's website in April of this year. 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 between each collision with an atom than they lose in the collision, thus speeding up to high energy.

In FF-1, when the current pulse is just starting and the gas in the device is mostly neutral, very large fields build up as the electrons try to push their way through the resisting gas. With very few electrons able to move, the ones that do have to travel fast to carry a given current. The fast-

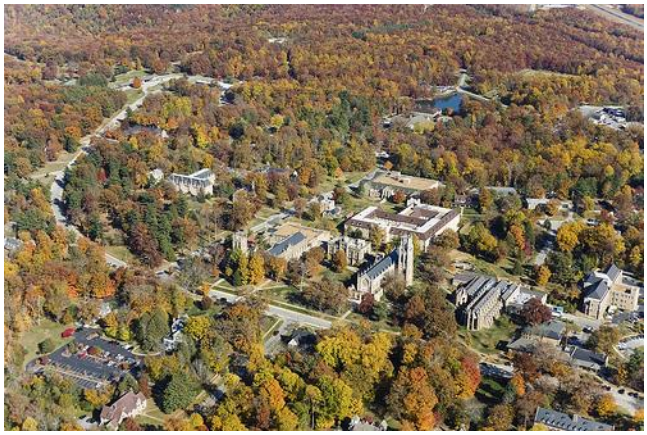
moving runaway electrons gain as much as 3 keV of energy, slamming into the anode and depositing enough heat energy to vaporize some of the metal. This vaporized metal becomes a major impurity in the plasma, disrupting the formation of plasma filaments and leading to lower density in the plasmoid that the current generates. Lower density in turn leads to much lower fusion yield.

This runaway mechanism is a second main source of impurities, the first being arcing between different pieces of the electrodes. While one-piece, monolithic electrodes will eliminate all arcing, more steps need to be taken to eliminate the runaway electrons. The most important is 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, there are lots of free electrons ready to move. With many electrons, the current can be carried with each electron moving slowly and thus having little energy. Thus runaway electrons don't occur in the main pulse either. High pressure in the gas, which make collisions of electrons with atoms more common, can help to prevent runaways as well.

Pre-ionization is a bit like deliberately creating a traffic jam. Runaway electrons are like cars on a highway at mid-day. There are fewer cars passing a given point but at a higher speed. These faster- moving cars, like the runaway electrons, are carrying more energy. At rush hour, there are far more cars passing a given point per minute, but they all move at a slower speed. Pre-ionization, by creating lots of free electrons, an electron "rush hour", allows a higher current with slower moving electrons, eliminating the fast runaways.

The paper will be available for free download from *Physics of Plasmas'* only until Nov.21, 2014.

Focus Fusion in Tennessee: LPP's Lerner Visits Sewanee, University of the South



Aerial view of the campus of Sewannee, University of the South

Bringing the latest news of fusion research to a Tennessee liberal arts college, LPP's Lerner led a seminar on Focus Fusion as the Fast Route to Fusion Energy on Nov.12 at Sewanee, University

of the South. The two-hour seminar with the college's Physics Department students and faculty was part of LPP's ongoing initiative to enlarge the audience for our work beyond the fusion community and those following fusion developments. During the seminar with a few dozen participants, Lerner explained the links between the basic physics of Maxwell's Laws, which underlie electromagnetic theory, and the way the dense plasma focus device works. The video of the seminar will be edited into an online seminar, which will be posted on LPPFusion's website in the coming months.

"We're looking for way to bridge the gap between what the average person knows—which is not much science—and what they need to know to understand how Focus Fusion works" explains Lerner. "This seminar, with a sharp group of physics undergraduates who had no previous courses in plasma physics, is part of our effort to boil down the basic concepts that we use to understand the DPF. If people get those concepts, then they'll know much more about what a necessary, safe and feasible technology this is."

After the seminar, Physics Dep't chair Dr. Randolph Peterson proposed that the department seek funding for joint student projects with LPPFusion, where students would bring instruments to the FF-1 facility to study the device's function. The proposed program might involve other Tennessee-region schools. Lerner thought this was a great idea and will help facilitate such programs with other universities as well.

Lerner's visit to Chattanooga involved two other events as well. In an earlier seminar with the Physics Department, Lerner described his and other recent work in cosmology—"Evidence that The Universe is Not Expanding", which led to a lively discussion with students and faculty. As well, Lerner gave a technical briefing on fusion research to a small group of interested specialists, including, Dr. Olin M. Ivey, Energy Fund Account Manager of the Tennessee Renewable Energy and Economic Development Council; Nick Wilkinson, Deputy Administrator for Economic Development of the City of Chattanooga and Michelle Harstine, aide to Congressman Chuck Fleischmann.