Lawrenceville Plasma Physics, Inc

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

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Summary:

- **LPP at Google Solve for X Fusion Brainstorming conference: still leading the field**
- **Moving the goal posts closer: quantum “herding” may allow net energy with lower density requirements**
- **Monolithic cathode planned to achieve plasma purity, higher densities**

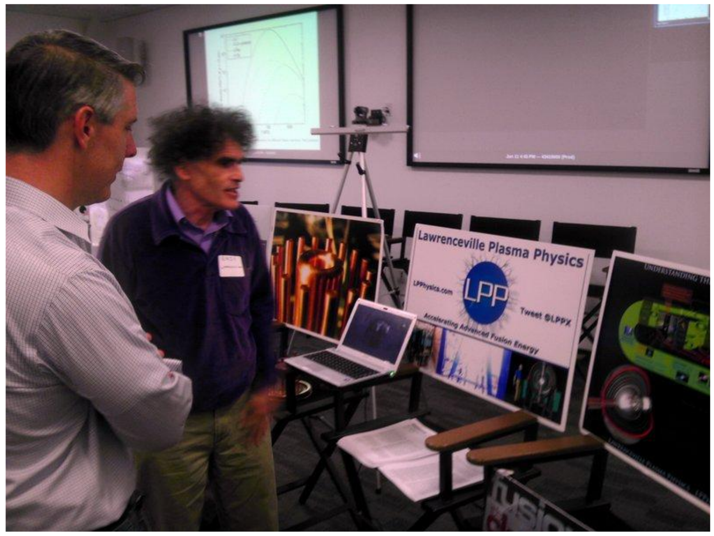
LPP leads the field at Google “Solve for <X>” Fusion Brainstorming Conference

On June 11, 2013, LPP participated in Google’s “Solve For <X>” Fusion Brainstorming Conference in Mountain View, California. Solve For <X> encourages projects to solve the toughest technological challenges of our day. The participants were scientists from Lawrenceville Plasma Physics, Inc. and three other leading fusion energy research companies: Tri Alpha Energy, General Fusion, and a project supported by giant multinational Lockheed-Martin. Teams of three presenters from each participating company were joined by a panel of nine fusion experts from top academic and national fusion laboratories: Princeton Plasma Physics Laboratory, MIT, the University of Wisconsin, and UCLA. Google has posted the shorter, general presentation at https://www.solveforx.com/moonshots/aneutronic-fusion. A second presentation given that day, with more scientific details, is available here.

L-R: Solve for <X>’s Dan Piponi and MIT’s Bruno Coppi watch Google co-founder Sergey Brin deliver a brief greeting to the gathered fusioneers.

The reports given by the participants confirmed that, at the moment, LPP has achieved the best fusion results by far. LPP reported a density-time-temperature product over 2,000 times higher than that of Tri Alpha, despite Tri Alpha’s much larger, 150-person research team. Both of the other efforts are at considerably earlier stages of development. Professor Masaaki Yamada of Princeton commented on the great progress LPP had made since Dr. Yamada had last looked at the project after LPP’s 2007 presentation at Google

Tech Talks. In particular, LPP's results with confined plasma temperatures of 1.8 billion degrees, reported last year in the leading journal *Physics of Plasmas*, were far higher than the 6 million degrees reported by the Tri Alpha team.



LPP's Eric Lerner discusses Focus Fusion with a Google attendee at the event.

Two proposals emerged with broad support out of a lively discussion of the direction of fusion research. One was to draft an open letter to the US Congress urging that the US fusion energy research effort be expanded to include alternatives to the now almost-exclusive focus on the ITER tokamak project. Participants were united in their views that the present fusion program is too narrow. A draft of this letter is now being circulated for comments and finalization. A second proposal was some form of joint collaboration on simulation and data analysis. Participants made no firm decisions, but agreed to carry on further discussion about these and other proposals for action.

There was also a good exchange of views covering the benefits and challenges of aneutronic fusion. Both LPP and Tri Alpha are aiming for fusion with aneutronic fuels that produce no neutrons, and thus no nuclear waste. LPP's President and Chief Scientist, Eric J. Lerner, pointed out in his presentation that aneutronic fuels also could potentially be much cheaper than any existing energy sources, as energy could be converted directly into electricity, avoiding the cost of steam turbines and generators usually used for conversion. Other scientists agreed that eliminating neutrons from the main reaction would greatly simplify materials problems encountered using neutron-reducing fusion fuels like deuterium-tritium. Neutrons tend to destroy the materials that a DT reactor is made of, and aneutronic fuels avoid this problem. On the other hand, aneutronic fuels require higher temperatures than DT does, and General Fusion's Michael Laberge felt that his team's liquid lead-lithium design would overcome neutron issues. The event was a great opportunity to see the progress in fusion research, and an important step forward in beginning cooperative actions.

Moving the goal posts closer: quantum "herding" may allow net energy with lower density requirements

Increasing the density of the plasmoid is the missing third leg of LPP's fusion tripod—with the first two legs of confinement and high energies already achieved, this greater density is what we need to get to net energy production. We know we must increase density a long way from our current results. But now it seems the goal post itself has moved somewhat nearer. New theoretical calculations indicate that an effect that was left out of previous calculations increases the fusion reaction rate at high magnetic fields and thus requires only about one third the plasma density we previously calculated. This reduces the improvement needed in density from about 10,000-fold to about 3,000-fold.

The new calculation is again based on the quantum magnetic field effect that LPP Chief Scientist Eric Lerner first applied to the dense plasma focus in 2003. This effect causes ions—nuclei—moving in extremely strong magnetic fields to transfer energy slowly to electrons. Back in 2003, we realized that this would keep the electrons cooler, so they would radiate less X-ray energy, making it easier to achieve the extremely high temperature needed for hydrogen-boron fusion. But until recently, we overlooked another beneficial effect.

In a typical plasma at low magnetic field, the nuclei move almost randomly on the microscopic level, so when two nuclei collide only about one third of their energy is directed along the line that connects them. At the very high magnetic fields, the situation is different. The nuclei in that case are moving almost exactly along the direction of the magnetic fields. So when they collide head-on, their full energy goes into the collision. Since the fusion reaction rate rises with energy, up to a very high energy, the more-head on collisions speed up the reactions for a given density. This means a plasma with higher magnetic fields can achieve the same reaction rate at a lower plasma density.

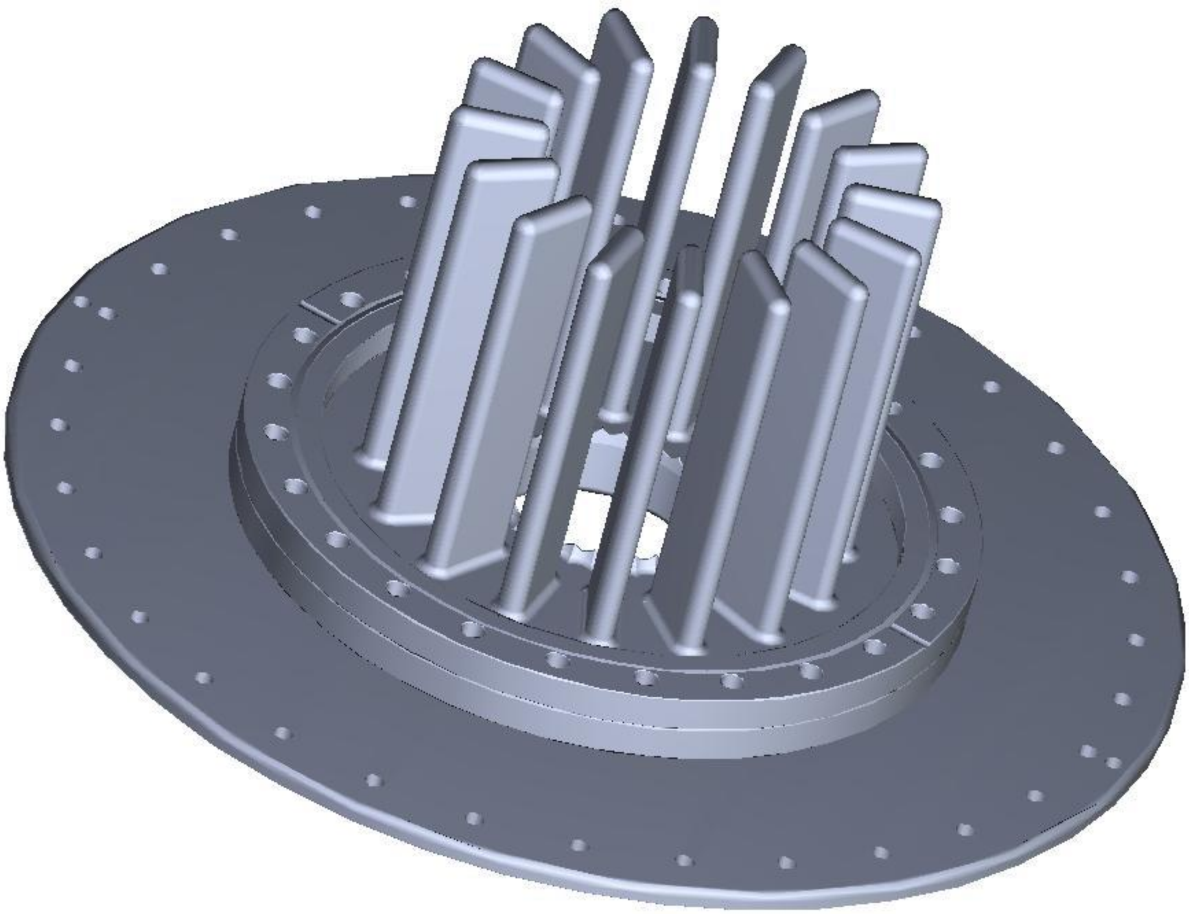
The reason this alignment along the magnetic field line happens at very high magnetic fields is because the quantum magnetic field effect operates only for ions moving in the same direction as the electrons—along the field lines. If the ions randomly move across the field lines, they lose energy much more rapidly to the electrons, forcing the ions back onto the field lines. Thus the electrons, through the quantum effect, act as sheep dogs, herding the ions into the magnetic field's direction, where they collide with each other head-on.

The result is to allow us to reach net energy production with somewhat less demanding density conditions—making our path shorter and easier. We'll be publishing a paper on this in the coming months.

Monolithic cathode planned to achieve plasma purity, higher density

Our latest round of experiments have convinced us that we will not be able to achieve the level of purity in the plasma we need for high density as long as we have joints between metal pieces in the cathode. Even with our very careful use of indium, sufficient contact resistance remains to cause significant vaporization of copper. So, despite the additional expense involved, we have decided to upgrade the cathode to a single monolithic piece of tungsten. This single piece will incorporate the cathode plate, the cathode rods and the underlying plate that attaches to the transmission plates that carry the current back to the capacitors. This will move any joins within the cathode to positions outside the vacuum chamber. Both our experimental experience and materials theory indicates that vaporization from the tungsten itself should be minimized, and should fall well below the requirements we need. As far as we know, such monolithic construction is new for a plasma focus device design.

However, a key consideration in the new cathode design is the brittleness of tungsten. Complex tungsten pieces like ours are formed by sintering—pressing together tungsten powder. This process does not give the tungsten its full strength and makes it vulnerable to sudden impacts. When the current flows through the electrode, the magnetic field will force the cathode outwards while it pinches the anode inwards. So we have to design the new cathode to withstand repetitive sudden stresses of this sort. One possible design involves replacing the rods with vanes that will be much more resistant to these outward stresses, as shown below.



One of our summer undergraduate research fellows, Arya Ghaseminejad, is helping to prepare various design alternatives. These will be tested with CAD simulations with the help of LPP Board of Advisors member Rudy Fritsch. In this way we can ensure in advance that a new and more expensive monolithic cathode will also be long-lasting.

In order to measure in real time the amount of metal impurities in the plasma, we have purchased a digital UV spectrometer. From the ratios of the strengths of the bright lines produced by deuterium and by the metals we should be able to calculate the impurity levels for each shot. Our other undergraduate research fellow, Kyle Lindhiemer, will be calibrating this spectrometer and we will probably be doing some shots with the old cathode to get a baseline comparison for our monolithic model.