Lawrenceville Plasma Physics, Inc

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

Focus Fusion Report

December 3rd, 2012

- **Arcing problem looks solved, leak delays new tests**
- **Photos confirm plasmoid structure**
- **SESAME's Israel-Iran cooperation shows Fusion for Peace is no pipe dream**

Summary: Two shots with no arcing indicate the problem is solved, although more proof is needed. A leak held up key tests while we implement a solution. Analysis of photos taken in October confirms our understanding of plasmoid structure. The SESAME physics cooperation project, involving both Israel and Iran, shows that intergovernmental research like our Fusion for Peace proposal is feasible politically.

Arcing appears to be solved for now, but a leak causes delay

Two shots fired by LPP's FF-1 dense plasma focus on Nov. 13 may have signaled the end of a months-long effort to overcome arcing within the device. Arcing, the uncontrolled jump of electric current between two conductors which leads to vaporization of the metals, has interfered with our efforts to achieve symmetric compression of the plasma and the high densities we need for higher fusion yields. By November 10th, we had installed a new all-tungsten cathode plate to eliminate arcing within the former hybrid plate, which consisted of a tungsten ring of teeth vacuum brazed to a copper plate. The teeth help form the plasma sheath. We carefully tested with our new micro-ohmmeter to confirm in advance that the indium seal between the tungsten and the steel it rests on had extremely low resistance, too low to allow arcing.

Unfortunately, when we assembled the vacuum chamber, we found a very large leak, allowing air to enter the chamber 100 times faster than our normal rate. We decided to fire the machine twice to see if the arcing was eliminated, even though we knew that the uneven mixing of gases caused by the leak would prevent any compression and fusion from taking place.

When we disassembled, we saw that the insulator was absolutely clean, with no metallic residues from arcing, and there was no microscopic evidence of arcing on either the anode (the central electrode) or the cathode (the outer electrode). Since the two shots involved as much as 1.2 MA of current and since arcing almost always starts from the first shot, this is strong evidence that arcing has been eliminated. Of course more testing is needed to be absolutely certain, and the battle against arcing is ongoing as arcing may recur when we move to still higher currents, but the results were a major step forward for the project.

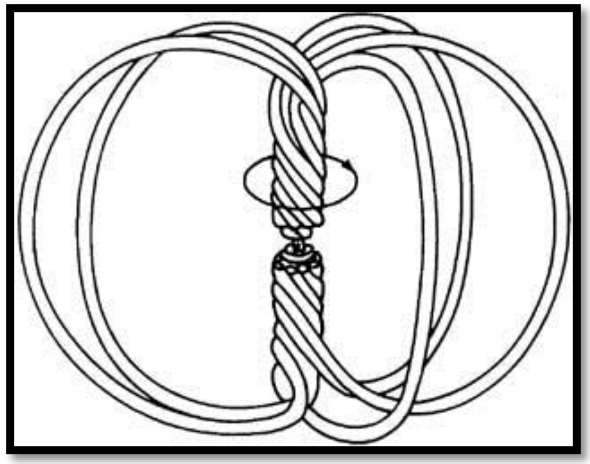
Above: The previous, now broken insulator (background) shows arcing, with a dark horizontal mark below where the insulator should be exposed to plasma. In the foreground, the most recent insulator is pristine below the sawteeth where the plasma sheath forms.

We could not find the origin of the leak for two weeks. Our routine method of leak detection, spraying isopropyl alcohol on possible leak areas and seeing if the alcohol seeped in to cause a spike in pressure, did not turn up anything. We did detect various smaller leaks from worn parts, which we repaired.

Finally, we rented a highly sensitive helium leak detection instrument and filled the vacuum chamber with helium to find where it leaked out. Initially we were even more mystified as no leak showed up, but as we carefully inched our way around the upper plate of the machine, the indicator started to shoot up—25, 50,200, then 275 parts per million of helium. We had found the leak! The only path to this point from the vacuum chamber proved that the leak came from a failure of a rubber O-ring to seal properly against the anode. We have done a redesign of this seal and are implementing it in early December, hopefully paving the way to seeing better performance out of FF-1 without the interference of arcing.

At left: Eric points with some relief to the area showing high helium concentration, indicating the pathway to the location of our soon-to-be-fixed leak. In his right hand he is holding the needle probe of the helium detector.

FF-1 photos confirm plasmoid “apple core” structure



As shown in the [Focus Fusion animation](), our theory envisions the formation of the plasmoid as a kinking process caused by the twisting up of the filament which carries the current. Nearby kinks, having current moving in the same direction, attract each other, eventually twisting up into a characteristic shape, shown below with a dense “apple core” surrounded by an outer halo of filaments. Because the outer filaments are less dense, they are hard to photograph, and the plasmoid itself is only stable for 30 ns, so the exact moment is difficult to catch.

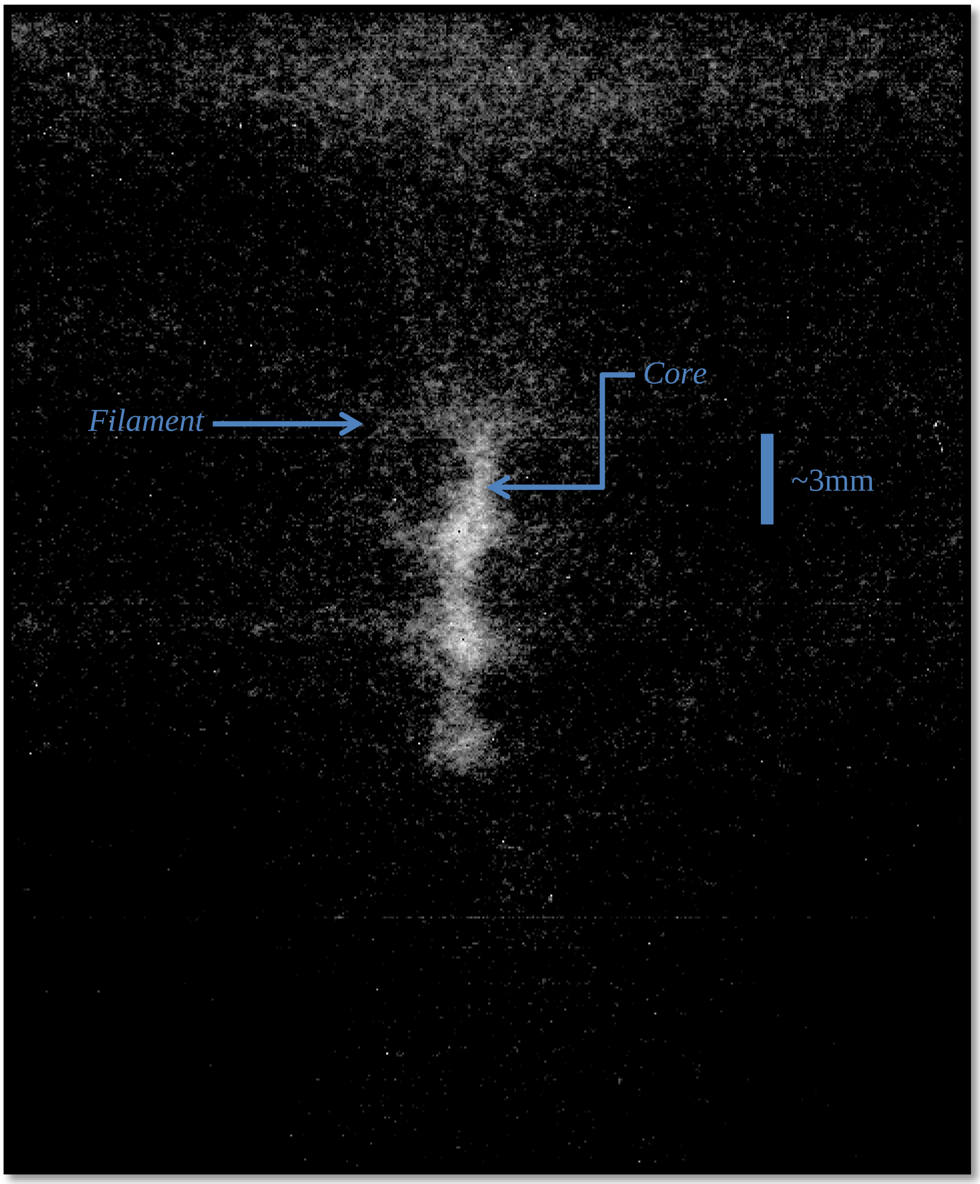


Figure 1. ICCD image of the center of the plasmoid.

Reviewing photos taken in October with our 200 ps exposure ICCD camera, we saw two images that clearly show the predicted structure. In Figure 1, shot 3 October 17th, which has been considerably contrast-enhanced, a typical plasmoid is forming on top of the twisting filament, and the "apple core" shape is clear. Much fainter, but visible, are the outer filaments arcing from the top to the bottom of the core.

A slightly later stage, with a more condensed core, but less visible outer filaments, was captured the next day, October 18th in shot 5. It is shown below in Figure 2, without enhancement.

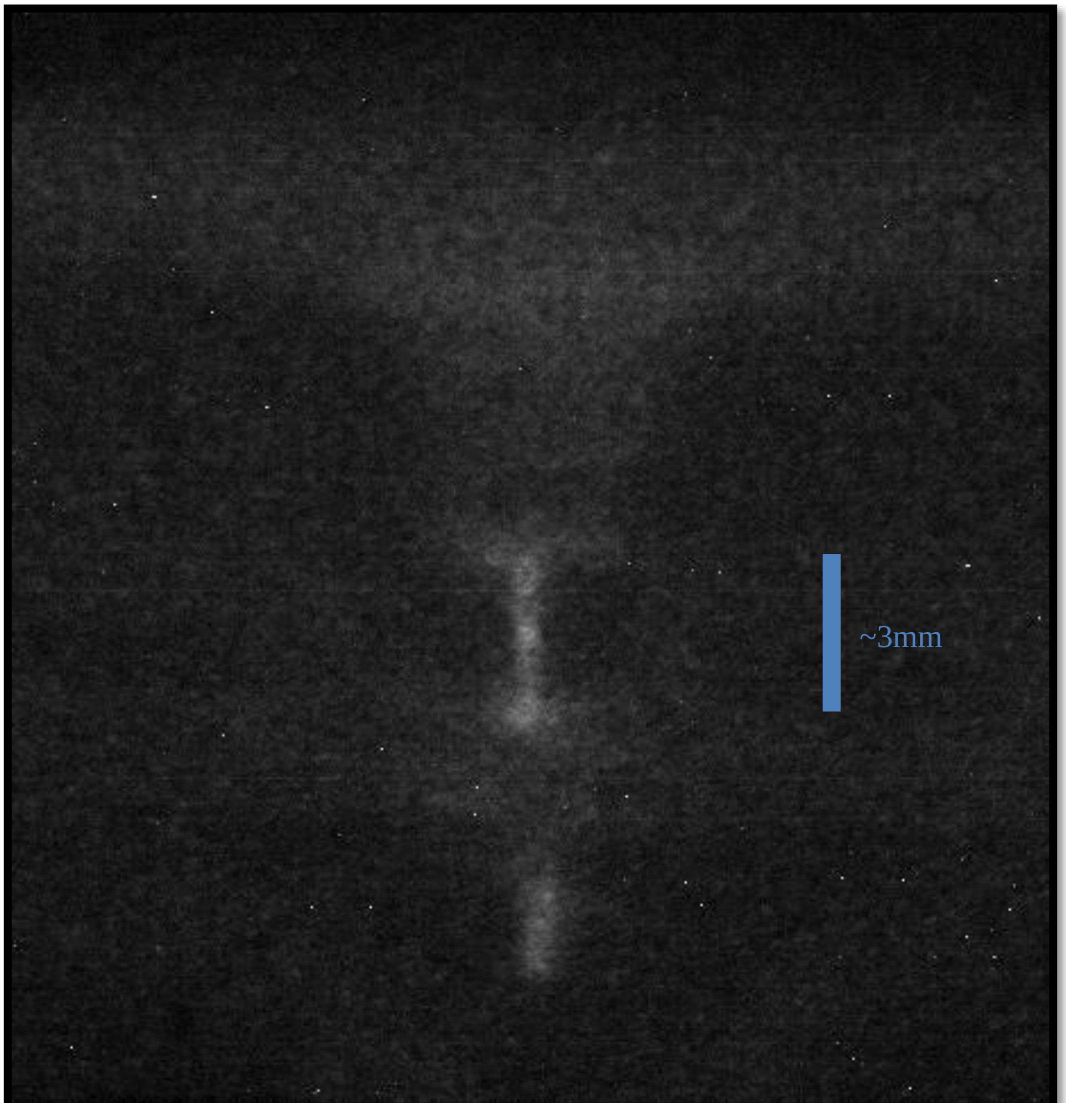


Figure 2. A slightly later stage image of the center of the plasmoid.

The core here is fully condensed, although its overall size and density are limited by the arcing asymmetries that were still occurring in October. There is a hint in the bright spot at the center of the core that some secondary kinking was starting to occur.

We expect future plasmoids will be smaller and denser, pushing beyond our present resolution of 60 microns per pixel. LPP Electrical Engineer Fred van Roessel is now preparing an additional lens set-up that will give us about five times better resolution of a smaller field of view.

Israel and Iran Cooperate in SESAME project, showing way toward Fusion for Peace

On November 25, BBC ran an amazed and enthusiastic news segment on the SESAME project, an international physics research facility in Jordan. The journalist was amazed because SESAME, which stands for Synchrotron-light for Experimental Science and Applications in the Middle East, is run by a consortium of Middle East governments which includes those of both Iran and Israel. Synchrotrons are a type of particle accelerator, which in this case is used as a source of focused, high-energy radiation for a range of physics research purposes both in basic and applied science.

While the BBC report gave widespread attention to the project, the project itself is not new. It was started in 1999, when Germany donated the synchrotron. It was set up under the auspices of UNESCO and at present the consortium includes, in addition to Israel and Iran, Bahrain, Cyprus, Egypt, Jordan, Pakistan, the Palestinian Authority, and Turkey. As can be imagined, the project has not had a smooth history, with budgetary problems repeatedly delaying completion of the facility (sounds familiar!), now scheduled for 2015. Nor have the participants in the project been insulated from the deadly conflicts in the region. Two of the Iranian scientists involved in SESAME were assassinated in 2010. But through it all, the scientists working on the project have cooperated amicably with each other, and all the governments have continued funding it, although not at a steady pace.

If the government of Israel could cooperate with that of Iran for 13 years on a physics research project, then clearly the government of the United States could also cooperate with that of Iran in the Fusion for Peace project, to build an International Center for Aneutronic Fusion, as LPP's Eric Lerner and Iranian and Japanese physicists have proposed. It is time to get such cooperation started!

(Thanks to James Miller, Oxford International Development Group, for bringing SESAME to our attention. He is involved with another cooperative project where US and Iranian doctors are working to bring some of Iran's models for rural medical care to rural Mississippi.)