Report August 28, 2024

Summary:

- **Modified Beryllium Electrodes Assembled—Bake Out Begins**
- **Control Data Confirms Filament, Asymmetry Hypotheses**
- **US Government Decides—Fusion Energy is Not Nuclear Energy**
- **ITER Faces Major Delays**
- **Reg D Campaign to End Sept. 15**
- **Next Evolution of Physics Study Group: Planck's Discovery of Quanta**

Modified Beryllium Electrodes Assembled - Bake Out Begins

LPPFusion Research Scientist Dr. Syed Hassan, assisted by Chief Scientist Eric Lerner, has completed the successful assembly of FF-2B with our new modified beryllium electrodes. The next step is a bake-out to rid the vacuum chamber of water vapor and then on to our exciting first effort to burn boron—to achieve fusion with the hydrogen-boron reaction.

Dr. Hassan had to carry out a number of exacting steps to complete the assembly, all the while maintaining LPPFusion's strict safety protocols to prevent contamination with beryllium dust. First, using our sealed glove box, Dr. Hassan merged the new anode onto the anode plate. To ensure ultralow resistance, he used indium to join the parts together. The parts were first heated to melt the indium, then the indium was spread onto the parts with an ultrasonic soldering iron. The ultrasound produced by the iron, similar to that used in a dentist's office to clean teeth, breaks up the thin layer of oxide on the metal parts, allowing the indium to fuse onto the part. Once the right temperature is reached, the indium spreads as easily as paint. Lerner's measurements showed that the resistance across the joints was less that 2 microohms, an excellent result.

Dr. Syed Hassan, in full protective gear, does final preparation to put the new beryllium anode plate (with anode hidden underneath) onto the FF-2B device.

To remove the thin oxide layer from both the anode and the reprofiled cathode, Dr. Hassan hand-polished each. This step is important, as it prevents the vaporization and redeposition of a messy oxide layer. This occurred in our first beryllium assembly in 2019 but was avoided by polishing in the second assembly in 2021.

However, in order to prevent the beryllium parts from re-oxidizing when exposed to the air during assembly, the team had to do the entire assembly in a single day. Dr. Hasan and Lerner worked to carefully center the ceramic insulator within the cathode and the anode inside both, to prevent asymmetries in the plasma breakdown (see next news item.) They used a new procedure, suggested by Dr. Hassan, in which the cathode and insulator were first centered on each other and the connecting bolts tightened, while the anode remained unbolted. This result in excellent centering of the insulator, but the anode was 0.125 mm(0.005 inch) off-center, potentially a big error. However, with a tiny shove of a screwdriver on the anode steel plate, Dr. Hassan flicked the anode into perfect centering and bolted it down. Lerner measured the centering from below the anode to be better than 25 microns, so one side of the anode is not more than 5% closer to the insulator than the other side.

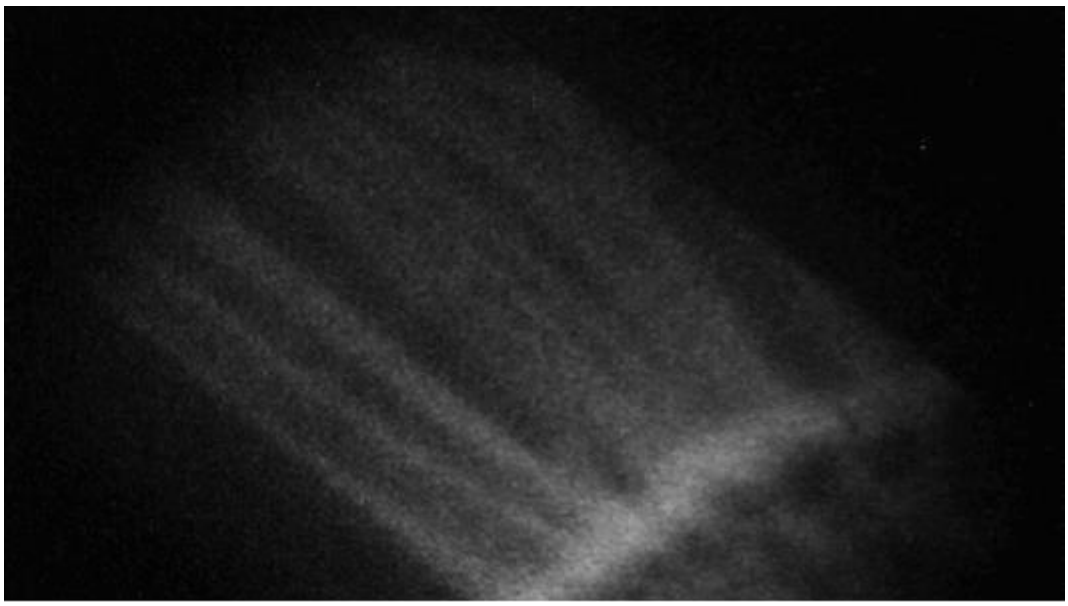
To complete the assembly of the vacuum chamber Dr. Hassan had to work well into the early morning hours of Aug. 23. This is not something we do routinely at LPPFusion! We hope by the time of the next major assembly we'll have more help to spread the work.

With the bake-out expected to last two weeks at most, we still expect to initiate tests with the new assembly in September. After a preliminary week of shots with deuterium, we'll move directly to our long-awaited tests with decaborane—a compound of hydrogen and boron.

Control Data Confirms Filament, Asymmetry Hypotheses

For a long time, Lerner has hypothesized that the filaments in LPPFusion's DPF devices are being disrupted before they can compress into the plasmoid, leading to much lower plasma densities in the plasmoid and much lower fusion yields than are theoretically possible. The team had images showing the filaments forming early in the pulse, and being absent at the pinch that forms the plasmoid, but had never confirmed the process of filament disruption nor detected when the filaments disappeared. During the control shots with the tungsten electrodes, at the end of July, Dr. Hassan succeeded in getting a series of images, using our ultra-fast ICCD camera with a series of shots under the same conditions, that show clearly the disruption of the filaments during the rundown.

The images below show the story. The field of view is shifting for each image so the current sheath is being followed as it moves down the anode. As can be seen, the filaments start expanding by 830 ns, are nearly gone by 1030 ns and are entirely gone by 1230. So they cease to exist somewhere around 1100 ns.



630ns, 830ns, 1030ns and 1230ns

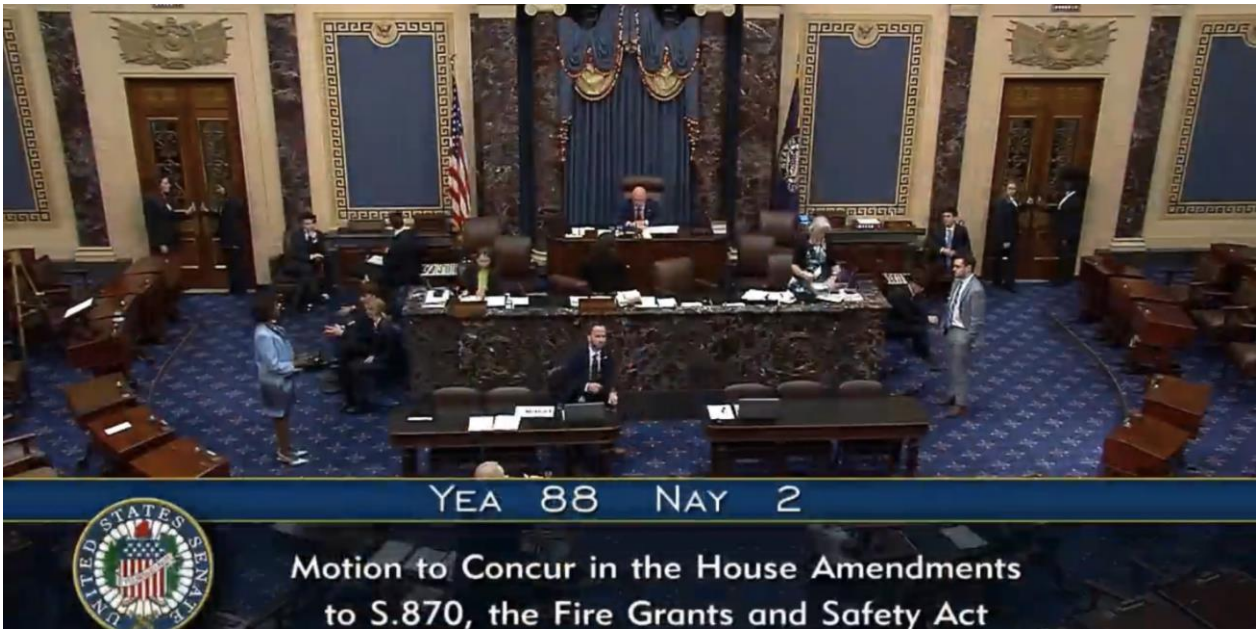
These observations confirm Lerner's theoretical calculations that the filaments must carry a certain critical level of current required to prevent disruption. With the tungsten electrodes and the originally-profiled beryllium cathode, too many filaments were produced, reducing the current in each filament below the critical level. Lerner expects the new profile on the cathode will cut the number of filaments in half, providing the critical current needed to prevent filament disruption. As well, when the team switches to hydrogen-boron fill gas, the greater charge on the boron ions will help to confine the filaments, as the pinch forces increase as the square of the ionic charge.

In addition, as we have reported previously, the 10-cm anode control tests seemed to be impaired by a strong asymmetry in the current sheath, which was repeated in each shot. On disassembly, part of the reason for this asymmetry became clear—the anode was off-center relative to the cathode and insulator—as shown by the asymmetric patterns of deposition seen on both the anode and insulator. Again, the asymmetric sheath also contributed to a poor compression and a too large and un-dense plasmoid. Fortunately, the team identified the error made in centering the anode in the last assembly, when the centering could not be measured from below the

electrodes. This error was certainly not repeated in the new assembly, so the symmetry should be greatly improved in the upcoming tests.

The 10-cm tungsten anode shows clear signs of being off-center during assembly. The dark and bright areas mark the end of the insulator on the two sides of the anode and both the deposition below the line and the erosion above the line show that the anode was much closer to the insulator on the left-hand sector than the right. The new beryllium assembly is far better centered.

US Government Decides: Fusion Energy is Not Nuclear Energy



In a huge regulatory win for fusion energy development, the US Government codified the permanent separation of fusion energy regulations from those for nuclear fission. On June 18, in a bipartisan 88-2 vote, the Senate passed S.870, the Fire Grants and Safety Act, which included the Fusion Energy Act, and President Biden signed it into law July 9th. This Act amends the Atomic Energy Act of 1954 to add a new definition of "fusion machines" as particle accelerators. That clarification confirms a previous decision by the Nuclear Regulatory Commission, making it US law.

The US government has long defined" nuclear energy" to mean energy derived from the fission chain reaction. However, until recently it had been unclear how fusion energy would be regulated. The significant threat was that economic interests that stood to lose from the development of fusion energy, such as the fossil fuel industry, might influence the regulation process to improperly lump fusion energy with fission energy, slowing fusion development and deployment.

But now that threat has been averted before fusion energy is even ready for deployment. By classifying fusion energy devices with "particle accelerators" the new law ensures that the US will not use any improper regulations for fusion, but just the standard safety regulations that govern any machine that generates high-energy particles. Given the US weight in the world economy and its influence in world regulations, this decision will probably set a precedent for regulators elsewhere.

This big victory did not come about by accident. Since its founding, the Fusion Industry Association, headed by Andrew Holland, has been informing regulators at the NRC and legislators in the Fusion Energy Caucus, their staffs and many others about the need for separate regulation of fusion energy. This work has now born fruit by clearing out of the way what could have been a big potential obstacle to fusion energy for all.

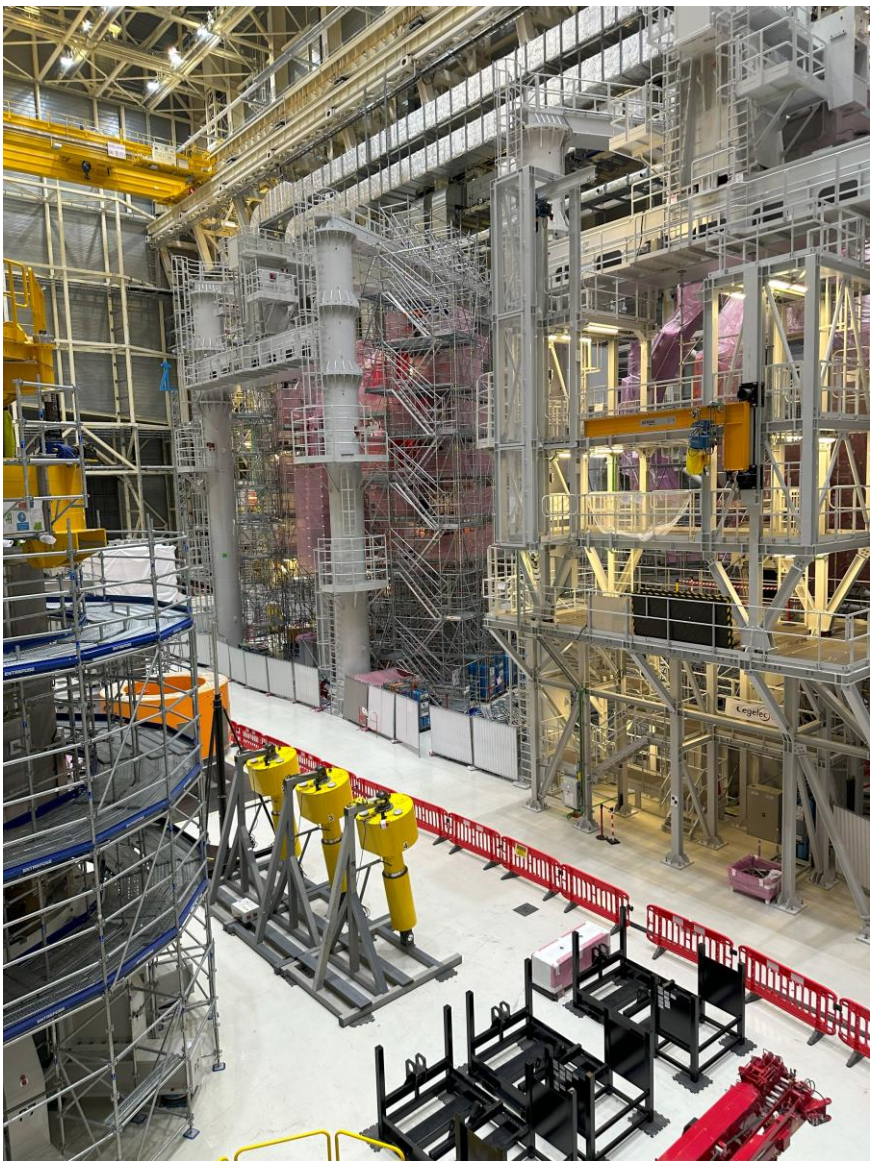
ITER Faces Major Delays

On June 20 (we're catching up with the news after our intense work in the lab) the leaders of the International Tokamak Experimental Reactor (ITER) project announced a decade-long delay in their plans for operation of the giant machine, the world's largest fusion experiment, which is still under construction in southern France. Initial operation which had been planned for 2025, has now been pushed back to 2035. Since the last schedule had been announced in 2016, the time remaining in construction has now actually lengthened from nine to eleven years.

Whether this schedule will also face revisions is an open question. An additional 5-6 billion dollars will be needed to fund the added years of work.

As had been widely reported previously, the delays were needed because two of the three giant sets of parts that make up the planned machine were found to be faulty. Each set of building-sized parts had been built in eight different locations around the world. The most complex set, the magnetic coils, were actually the only ones made correctly. The innermost layer, the vacuum vessel that will surround the hot plasma, had been improperly welded and could not fit together with the required mm-sized tolerances, so will have to be re-machined and re-welded on site. The outermost layer, the thermal blanket that was to remove the energy that the ITER device would hopefully generate, had extensive leaks in its cooling pipes, which will have to be removed and replaced, again at great cost. Ironically, but perhaps predictably, the errors had been made because of cost-cutting decisions by ITER management.

The large delays have raised significant questions about the viability of the project. Not only LPPFusion, but most private fusion companies expect that they can demonstrate commercial fusion energy production before 2035. Of course, their plans could be delayed as well, but there is certainly a large possibility that ITER could be obsolete before it ever operates.



A portion of the giant ITER assembly room awaits the repaired parts.

Reg D Campaign to End Sept. 15

LPPFusion's 2024 Wefunder campaign will end soon. Unlike ITER, we don't need billions, but we do need more than we have. We are aiming to get to $400,000 before the campaign ends, which is still $194,000 away. But we know a lot of investors wait until the last minute to invest, so we can still make our goal, but only with your help!

Our simultaneous Reg. D offering will close on Sept.15. We absolutely need to reach $ 1million in investments and pledges to complete our accredited- investor syndicate. Doing so will trigger investors with $500,000 in pledges to actually invest this money, giving us the cash we need to hire two more full time staff and have the money in the bank we need for sound financial planning and functioning. If you are an accredited investor who can invest $5,000 or more, we need you. We need only $106, 000 to make our goal here. Just four $25,000 pledges or investments will take us over the top!

Next Evolution of Physics Study Group: Planck's Discovery of Quanta

The next class will start the part of the series on the "Revolution in Physics" that created modern physics during the years 1895-1940. There are four threads to this story: quantum mechanics, relativity, nuclear physics and plasma physics. In sticking to a broadly chronological structure, the next classes will deal with the first twenty years of this period 1895-1915.

We'll start with Planck's discovery of quanta and then cover in subsequent classes the initial phases of nuclear physics, plasma physics and relativity. The main reading is the introduction and Chapter 1 of George Gamow's book "Thirty Years That Shook Physics" . Zoom link follows:
When: Sep 7, 2024 02:30 PM Eastern Time (US and Canada)

Register in advance for this meeting:
https://us02web.zoom.us/meeting/register/tZYude6trzguH9LQ2PgvTztizW-ZBjuM6wpG

After registering, you will receive a confirmation email containing information about joining the meeting.