Reactor Status Updates from FPA fusion conference 2015

The Annual Fusion Power Associates meeting brings together top fusion, plasma and related scientists from around the globe for a frank presentation and discussion of progress and strategies. This year's was titled Strategies to Fusion Power. Here is a quick overview of updates on the various approaches to generating fusion power that were presented at the conference

ITER

The first technical presentation was on the largest fusion experiment in the world when completed, the International Thermonuclear Experimental Reactor located in Cadarache, France. It is an international collaborative effort between 6 countries (U.S., Japan, India, China, EU, Korea, Russia). Its goal is to demonstrate the ability to generate 500MW from 50MW of input power.

Bernard Bigot, Director-General, ITER Org., presented the status of ITER. Bigot elaborated the immense requirements of the project, technically and socially, and gave a breakdown of each participating country's share of production. This included 2,800 tons of superconductors (200km made over 8 years, 70% of total required), which have already been manufactured—the largest procurement of superconducting material in industrial history. Most parts to be produced, which likewise strain industrial capacity, are either currently in production or assembled. The project will require more than one million parts, more than 150,000 sequenced activities, and 1,200 suppliers. Pictures of the facility show some completed buildings, others have large cranes busily filling out their structures. The plan is to finalize design decisions within the next few months. Bigot's presentation was followed by Ned Sauthoff, U.S. ITER Project Office, who detailed the status of U.S. contributions to ITER.
http://fire.pppl.gov/fpa15_ITER_Status_Bigot.pdf
http://fire.pppl.gov/fpa15_US_ITER_Sauthoff.pdf

National Spherical Torus Experiment

Stewart Prager, lab director at Princeton Plasma Physics Laboratory, explained the upgrade to the National Spherical Torus Experiment (NSTX), one of three large tokamak fusion reactors in the United States, which finished construction in August 2015. The NSTX is a proof of concept spherically shaped device (rather than donut shaped) intended to achieve similar results to other tokamak reactors, but with less magnetic field requirement. In 2012 the NSTX closed to undergo an upgrade, which added a new, more powerful center magnet, doubling the magnetic confining field, as well as adding a second neutral injection beam, thereby also doubling the heating power, making the NSTX-U the most powerful spherical tokamak in the world.
http://fire.pppl.gov/fpa15_Fusion_Strategy_Prager.pptx

The Stellarator

The stellarator type of fusion reactor made news just the week prior to the conference as the largest reactor of this type finished its upgrade and ran its first plasma experiments. In tokamak reactors, the plasma tends to drift outward, away from the center. A brilliant idea by Lyman Spitzer at Princeton was to make a device which twisted around, like a moebius strip twisted several times (or a cruller donut), such that as the plasma travels along, its outer wall becomes the inner wall, and the inner becomes the outer several times throughout the pathway. Thereby, as the plasma continues to drift “out” it continues on a circular path. It is hoped that this configuration will allow continuous operation, an important aspect of a power plant.

Germany’s Wendelstein 7X, the world’s largest stellarator, completed its four year upgrade and ran its first plasma experiment with helium on December 10, 2015. It has a major radius of 5.5 meters and a minor radius of 0.5 meters. [see video] The device uses 50 superconducting coils with a maximum magnetic field of 2.5T and is expected to run a heating pulse of 30 minutes. After testing out various components, it will test steady-state operation beginning 2019.

The second largest stellarator in the world is the Large Helical Device in Japan, which has been in operation since 1998 and has already achieved 54 minutes of continuous operation. It will also undergo upgrade starting February 2017.
http://fire.pppl.gov/fpa15_stellarator_approach_MCZ.pdf

Laser Fusion

Laser fusion is a very different approach from the reactors mentioned above, which use strong magnetic fields to trap a body of plasma as the plasma is heated to high temperatures and pressures. Lasers are used in fusion energy research in several different combinations. For example, the National Ignition Facility in Livermore, California, shoots 192 lasers, almost spherically, into the inner wall of a small (pencil eraser sized) gold capsule, which contains a small solid ball of fusion fuel. The walls in turn generate X-rays which impinge upon the fusion fuel until they compress the ball to conditions necessary to, ideally, have a controlled self sustaining fusion reaction. This indirect method of laser fusion is sometimes called X-ray drive laser fusion.

The OMEGA laser facility at the Laboratory for Laser Energetics (LLE) in Rochester, NY is the second major facility in the U.S. that use lasers for fusion research. It uses lasers to directly impinge upon the fuel instead of creating X-rays that interact with the fusion fuel. This method is called direct drive laser fusion and the LLE has made several advances in that direction.

A third use of lasers is employed at Sandia National Labs on the Magnetized Liner Inertial Fusion experiment (MagLiF). Progress on MagLiF was presented by Daniel Sinars, Senior Manager of the Radiation and Fusion Physics Group at Sandia National Labs. MagLiF first magnetizes a small cylinder as well as the fusion fuel inside. It then sends in a laser blast through a little window at the top of the cylinder that preheats the fuel. This is quickly followed by an incredibly strong surge of current which generates an inward magnetic field that draws the wires violently toward each other until they burst, squeezing and heating the fusion fuel at the center to fusion conditions.

Results of experiments over the past year have shown success though with lower than expected outcomes. The suspicions that the primary culprits impeding the process are an unconditioned (non-uniform) laser beam as well as the thickness of the window through which the beam enters the cylinder, are to be tested over the next two years at the OMEGA laser facility.
http://fire.pppl.gov/fpa15_MagLIF_Sinars.pdf

Hiroshi Azechi, Deputy Director of the Institute of Laser Engineering (ILE), Osaka University, presented the work on another variation of laser fusion in Japan. Japan has been working on the Fast Ignition Realization Experiment (FIREX). Fast ignition has two stages: after lasers have heated and compressed the fuel, directly or indirectly, a second, much more powerful laser is introduced to give a last kick. Japan's ILE uses a picosecond heating laser (LFEX) and a nanosecond implosion laser (GEKKO-XII). Aside from the steady progress in laser power, Azechi also laid out plans for a high repetition laser, taking much less time to charge up than current lasers. This would accelerate experiments immensely.
http://fire.pppl.gov/fpa15_ICF_LLE_McCrory.pdf

Field Reverse Configuration

Progress on a type of reactor which enjoyed much research in the 70s and 80s, but was largely cut out of budget in the 80s, was presented by Michl Binderbauer, chief technology officer of Tri Alpha Inc. Tri Alpha's C-2 Colliding Beam Reactor, creates and propels two self sustaining plasma structures at each other, which merge to form a plasma cylinder, held within closed magnetic field lines, called a field reversed configuration (FRC). This type of reactor has many advantages. One of these is that it requires less applied magnetic pressure to produce the same amount of plasma pressure as other designs (the ratio of plasma pressure to magnetic pressure, called beta, can be used as a measure of efficiency).

21st Century technology and diagnostics, a few hybrid concepts from various previous reactor designs, as well as some innovations of their own, have led to steadily increasing time for which the plasma configuration, and conditions for fusion, is maintained (pulse duration 8ms). The reactor will undergo an upgrade starting April 2016.
http://fire.pppl.gov/fpa15_TAE-Progress_Binderbauer.pdf

Videos and papers can be found on their website at http://www.trialphaenergy.com/.

These are just some highlights. Fusion research continues to progress worldwide, even in the United States, where funding levels rather express intent to kill it altogether, along with the future fusion represents. Powerpoints from the whole conference can be found on the Fusion Power Associates website at http://fire.pppl.gov/fpa_annual_meet.html.