Australian ITER Forum Website News Update 2/18

B.J.Green (20/2/18)

1. ITER Director-General, Bernard Bigot: "ITER is a global response to a global challenge"

http://www.foronuclear.org/en/news/latest-news/123467-iter-director-general-bernard-bigot-iter-is-a-global-response-to-a-global-challenge

Bernard Bigot, ITER's general director explains during this detailled interview that "fusion energy is clean and safe" and ITER represents the culmination of decades of international research towards the industrial explotation of fusion energy. Nowadays, 50 percent of the total construction work scope through first plasma is now complete. He belives that "in the second half of this century we will have accumulated enough knowledge and experience to create a large fusion industry".

Could you please give us a summary of the ITER project for readers that are not familiar with it?ITER is a unique research project that aims to duplicate, here on Earth, the nuclear reactions that occur at the core of the Sun and Sun-like stars—the fusion of hydrogen nuclei into helium and energy. As you can imagine, it is a huge technological challenge. But it is the key step to accessing a new energy source, one that could bring a decisive contribution to meeting humankind's ever-growing needs in energy. ITER represents both the culmination of six decades of international research carried out on hundreds of fusion machines worldwide and a decisive and indispensable step towards the industrial exploitation of fusion energy.

ITER is also unique in that it brings together seven partners representing 35 nations, half the world's population and 85% of its industrial production. Never in history have so many nations worked together to achieve a common goal. **ITER is a global response to a global challenge.**

100,000 kilometers of superconducting strands, 150 million degrees centigrade, 23,000 tons of reactor weight. These are some of the impressive numbers for this experimental fusion reactor. Is everything in this project equally immense?

Contrary to a fission reactor, which can be miniaturized to fit into a submarine or a space probe, **an energy-generating fusion machine is necessarily large.** In order to achieve a "burning plasma" that produces much more energy than that required to heat it, something that has never been done before, we need to heat and confine a large volume of plasma (~ 850 cubic metres). Some of the "impressive numbers" that you mention derive from the plasma volume or, in the case of temperature, from the necessary conditions to achieve the fusion of hydrogen nuclei.

What are the advantages of this technology, and the challenges for the coming years?

Fusion energy is clean, intrinsically safe and based on virtually inexhaustible fuels. It is clean because it does not generate CO_2 or greenhouse effect gases, nor does it produce long-life/high-activity nuclear waste. It is intrinsically safe because of the very nature of the fusion reaction and because there are never more than 2 grams of fusion fuels in suspension inside the machine at a given time. Besides, and this is one of the reasons why a burning plasma is so difficult to obtain and maintain, the fusion reactions simply stop when all parameters cease to be nominal. A Fukushima or Chernobyl-type accident is simply not possible in a fusion machine.

Now the fuels: fusion energy can theoretically be obtained through several combinations of light atoms. However, in the present state of our technology, it is the reaction between two hydrogen isotopes, deuterium and tritium, that is the most accessible—although it is very difficult to realize. Deuterium poses no problem: it is easily extracted from water. With tritium, it's a bit more complicated. ITER will consume the few dozen kilograms that are available worldwide and experiment tritium production in situ, inside the machine. We will use the neutrons produced by the fusion reaction to produce tritium from lithium, a metal that is as abundant and widely distributed as lead. So our fuels are water and lithium and they are indeed virtually inexhaustible. There is enough deuterium in a half-filled bathtub, and enough lithium in a laptop battery to cover the electricity needs of an average European for 30 years...

ITER is considered the world's most important research project. How do you handle your job as general director in a project of such large dimensions, and what are your priorities?

Becoming the ITER Director-General in March 2015 was not part of my professional plan. Following a long career in research, higher education and top government administration I had just completed two mandates as Administrator-General of the French Alternative Energies and Atomic Energy Commission (CEA) when I was asked by the ITER Council (the organization's governing body) to fill in the job. I had been closely associated with ITER since France's bid to host the project in 2003 and in 2007 I was delegated by the French government to act as High Representative for the implementation of ITER in France. I had a good knowledge of ITER and of the challenges the project was facing.

I accepted the Council's offer at a crucial moment in ITER history, when the project was entering into manufacturing and preparations for assembly. This new phase required a new organization—one tailored to meet the double challenge of delivering an installation that is both a research facility and an industrial facility. What we needed at that point and need even more today was integration. ITER is a complex structure, with a central team here in France and seven "domestic agencies" emanating from the seven ITER Members that are responsible for the in-kind procurement of machine components and installation systems. To achieve this integration, we needed a clear, centralized decision-making process under the authority of the Director-General. This being established and accepted by all, we could move on, as **"One ITER," to promote and establish a project culture based on shared values of excellence**, adherence to commitments, adherence to schedule and budget, and careful and effective use of public funds. And all the while making safety and quality our highest priority.

You lead a team composed of over 1,200 workers living in France but with multiple nationalities. What advice do you have, or what techniques do you use to lead teams with these characteristics?

The ITER staff hails from some 35 nationalities and needs to work as one entity, one large team bent on a common goal. How do we achieve harmony and efficiency? Through mutual respect and the understanding that each culture has its own work habits, traditions and "best practices." However at the end of the day, after well documented debates, decisions have to be taken and implemented by all. The global world we live in has not erased national particularisms. But instead of seeing this as a problem, we see it as an asset: we are building a project culture in a way that takes advantage of the diversity of these "best practices" to achieve an optimal result. And in case we forget these fundamentals, we can attend regular intercultural workshops and seminars... ITER is breaking new grounds and our experience is of great interest to intercultural professionals and students throughout the world.

Speaking of employment. The ITER website continuously publishes job offers. What type of profiles are you hiring?

Whatever the field considered, whether it is engineering, physics, finance or administration, **we are simply looking for the best, the most experienced, the most competent, and the most dedicated.** But there is more: ITER is an international organization. Whatever your nationality, the colleague you will share your office with or the manager you will answer to will be Russian, Chinese, Japanese, Korean, Indian, American, European... you have to feel comfortable with and stimulated by the challenges of working in such a multicultural environment. And of course you need to have a good command of English, which is our working language. I've often said that, when joining ITER you symbolically abandon your nationality. You become Iternational... Working at ITER is very demanding but it is also very rewarding. Can you think of something more exciting, more motivating, than contributing to a project that can change the course of civilization for thousands of years?

You get thousands of visits. What intrigues and piques the interest of visitors, and what type of groups attend your site?

We receive approximately 17,000 visitors every year on the ITER site. They come from all walks of life: students of all ages, politicians and government executives, industrialists, local senior citizens clubs... What strikes them all when they visit the ITER site is the concrete, spectacular reality of this project. When you see the Tokamak Complex rising five storeys high; the 30-metre-wide cryostat taking shape in its workshop; or the ring magnets (17 to 24 metres in diameter) being wound in an on-site winding facility, your vision of the future of fusion dramatically changes: you see it happening before your own eyes... And keep in mind that what's happening here on the construction site in southern France is only part of the global ITER project: in factories throughout the world, thousands of components and systems are being manufactured, tested and commissioned before being shipped and readied for assembly and integration.

What is the current situation of the work being done on the experimental reactor, and what were the latest advances?

A few months ago, in November 2017, we passed an important symbolic milestone: based on the stringent metrics that measure project performance, **50 percent of the "total construction work scope through First Plasma" is now complete.**For instance, design, which accounts for approximately one-fourth of the total work scope, is now above 95 percent complete; manufacturing and building, which represents almost half of the total work scope, is close to 53 percent complete. In terms of activities that need to be completed, ITER is now halfway to its first operational event – the production of its "First Plasma" at the end of 2025. The latest advances are the completion of the winding packs of the 18 vertical large superconducting coils; the welding of the cryostat base; the finalization of the 30-metre-high bioshield wall; the delivery of the three largest cold boxes ever built and of 18 helium compressors for the cryogenic plant.

When do you expect citizens will be able to use energy from fusion reactors?

A major figure in fusion history, the Russian physicist Lev Artsimovitch (1909-1973), used to say that "fusion energy will be available when society needs it." There is something quite profound in this prediction. It means that governments will only be willing to make the necessary human and financial efforts to develop fusion when it becomes obvious that we need that option to insure that humankind continues its economic, industrial and social development**.** ITER is a first and decisive step in this direction. Is an experimental installation that is indispensable to demonstrate the science and technology of future fusion reactors. After ITER, and before entering the industrial age of fusion energy, we need to experiment with a steady-state machine—DEMO—which will be closer to an industrial prototype.

My conviction is that **in the second half of this century, beyond 2060, we will have accumulated enough knowledge and experience to create a large fusion industry**—just like in the past decades we have created an oil, gas or nuclear fission industry. But like with any of these industries, the decision will be both technical and political and rest in the individual governments' and investors' hands.

While fusion arrives, do you consider that the current fission energy, in combination with renewables, is a good alternative to stall contaminating emissions?

The world has to be determined about drastically reducing greenhouse gases emissions. To achieve this objective there is no other option than to save energy and to develop nuclear and renewable energies. Nuclear energy in both forms, along with renewables, will be at the core of the energy mix of the future—and by "future" I mean the decades to come. They are the alternative of choice. However, **only nuclear energy, whether fusion or fission, can provide the strong and dependable "baseload" that the world's industrial, economic and social development calls for.**

One of the major challenges that nuclear fission is facing is keeping safety as the highest priority. In my opinion, the future of fission industry depends on our capacity to build and operate installations that guarantee the highest level of safety possible, and to develop solutions for the long-term management of long-life, high-activity nuclear waste. Fusion does not have these issues and will develop along with the new generation of fission reactors, such as the fast-neutron sodium-cooled solutions for which the French CEA is developing a demonstrator in partnership with several countries. Such reactors have the ability to burn the depleted uranium from fuel processing, of which large quantities are available. They also have a potential to burn the plutonium that results from spent fuel reprocessing, which account for most of the long-term radiotoxicity in spent fuels.

How would you rate the Spanish contribution to ITER exporting products and participating in its manufacture as well as hosting Fusion for Energy in Barcelona?

ITER has a very close relationship with Spain, and not only because Barcelona hosts the European agency Fusion for Energy, which manages the European in-kind contribution to the project. Spanish research centers such as CIEMAT play a crucial role in ITER by contributing to the development of diagnostic systems, plasma heating components, test blanket modules, and control and data acquisition systems. **Spanish industry has won several hundred million euros in contracts in a highly competitive market.** Its capabilities cover a wide range of areas, making it possible to participate in the construction of the ITER buildings and in the fabrication of many ITER components such as the vacuum vessel, magnets test blankets modules, plant systems, in-vessel components, remote handling, tooling, safety, instrumentation and control, and CODAC, to name but a few.

Would you like to add anything?

I would like to thank you for this detailed interview. **I hope I was able to convey to your readers the importance of ITER and fusion for our common future**and to communicate the enthusiasm and pride we all feel at contributing to a project of this magnitude. I would like also to thank the Spanish industry for the high quality of its contributions and their understanding of the critical importance of strictly respecting the delivery schedule.

2. Fusion power is coming

http://www.directoryimd.com/article/fusion-power-is-coming.html

In December 2017, the world’s largest science project, Project ITER, completed 50% of the ‘total construction work scope through First Plasma’. Scheduled for December 2025, First Plasma will be the first stage of operation for ITER as a functional machine.

In southern France, 35 nations are collaborating to build the world's largest tokamak, a magnetic fusion device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy based on the same principle that powers our Sun and stars.

The acronym ITER stands for International Thermonuclear Experimental Reactor. It’s also the Latin for ‘the way’.

ITER Members China, the EU, India, Japan, Korea, Russia and the US have entered into a 35-year collaboration to build and operate the ITER device. The experimental campaign that will be carried out at ITER is crucial to advancing fusion science and preparing the way for the fusion power plants of tomorrow.

Fusion energy is carbon-free and environmentally sustainable, yet much more powerful than fossil fuels. A pineapple-sized amount of hydrogen offers as much fusion energy as 10 000t of coal.

"The stakes are very high for ITER," writes Bernard Bigot, PhD, director-general of ITER. "When we prove that fusion is a viable energy source, it will eventually replace burning fossil fuels, which are non-renewable and non-sustainable. Fusion will be complementary with wind, solar and other renewable energies. ITER's success has demanded extraordinary project management, systems engineering, and almost perfect integration of our work. Our design has taken advantage of the best expertise of every member's scientific and industrial base. No country could do this alone. We are all learning from each other, for the world's mutual benefit."

Three conditions must be fulfilled to achieve fusion in a laboratory: very high temperature (on the order of 150 million degrees Celsius); sufficient plasma particle density (to increase the likelihood that collisions do occur); and sufficient confinement time (to hold the plasma, which has a propensity to expand, within a defined volume).

ITER will be the first fusion device to produce net energy, to maintain fusion for long periods of time, and to test the integrated technologies, materials and physics regimes necessary for the commercial production of fusion-based electricity.

ITER recently passed a significant milestone: according to the stringent metrics that measure project performance, 50% of the 'total construction work scope through First Plasma' is now complete.

3. Nuclear fusion: the end of our energy problem?

By Francesca Church, CNN
Updated 1036 GMT (1836 HKT) January 25, 2018

(CNN) Professor Thomas Klinger heads up one of the world's most advanced nuclear fusion projects at the Max Planck Institute in Greifswald, Germany, where 400 scientists from around the world have invested over one million manpower hours to build the Wendelstein 7-X, a prototype nuclear fusion reactor.

It's called nuclear fusion: a method to produce energy which promises to be limitless, clean and accessible to all.

Nuclear fusion is the same process that powers the sun, and it's what scientists are trying to imitate to create a power source on earth that could one day replace fossil fuels entirely, offering limitless and clean energy.

For the moment, this is just a test, since it consumes far more energy than it creates. But it will provide valuable data if we are ever to build a nuclear fusion power plant.

This is a different process from the one used in traditional nuclear plants, which use fission. The risks associated with these plants have resulted in accidents such as Chernobyl in 1986 and the Fukushima disaster in 2011. Nuclear fusion, which Klinger and his colleagues are working on, promises to be safe, and generates no radioactive waste or other byproducts.

To explain how it works, Klinger uses a simple analogy: "It's like a pool billiards game," he says, describing nuclear fission as the moment when the balls on the table first break, and nuclear fusion as individual balls colliding.

"Nuclear fusion is fusing light nuclei, nuclear fission is splitting heavy nuclei. The fuel we are using from nuclear fusion is much more energy efficient, it's 10 million times more energy efficient than burning coal."

Nuclear fusion has been studied for decades and the Wendelstein is one of a number of fusion projects worldwide. Among them is the ITER project in Southern France, partly funded by the European Union. But Klinger affirms that the manpower, brainpower and over $1 billion of investment here in Northern Germany are worth it.

"Wendelstein 7-X is clearly one of the most advanced machines in the world, and it's also a big hope."

4. US must stay part of ITER, warns panel

News & Analysis Physics World February 2018

http://live.iop-pp01.agh.sleek.net/2018/01/25/us-must-stay-part-of-iter-warns-panel/

The US will be left isolated in fusion research if the country quits the ITER experiment that is currently being built in southern France. The warning comes in a report from the US National Academies of Science (NAS), which says that leaving ITER would require the US to develop a completely new approach to studying fusion. The current administration has not yet, however, shown any intention to abandon ITER.

The first of a two-phase study about US magnetic-confinement fusion research, the NAS report was commissioned by former US energy secretary Ernest Moniz and sponsored by the Department of Energy. While Moniz, who is a physicist, recommended when he was in office that the US should remain in ITER until 2018, he noted that the US should re-evaluate its membership before the 2019 financial year, which begins next October.

The report concludes that research on burning plasma is essential to develop magnetic-fusion energy and that the US has made “leading advances” in that area. It also notes that building and operating a burning plasma experiment is a “critical, but not sufficient next step” toward the realization of commercial fusion energy. “Burning plasma is an important aspect of getting to viable fusion energy; the only project that is in a position to reach a burning plasma is ITER,” says Melvyn Shochet, a particle physicist at the University of Chicago and a co-chair of the 19-member panel that wrote the report.

It also notes that, unlike its international partners, the US lacks a national plan that will lead to a fusion-energy demonstration device and that recent closures of domestic experimental facilities “threaten” the health of the field in US. As a result, the report calls for the US to maintain its membership of ITER.

“The US benefits from international co-operation to combine the scientific and engineering expertise, industrial capacity, and financial resources necessary for such as an inherently large project,” the panel asserts. “[Withdrawing] from the ITER project could isolate US fusion scientists from the international effort and would require the US to develop a new approach to studying burning plasma.”

Peter Gwynne
Boston, MA

5. News story

UKAEA launches National Fusion Technology Platform

Oxford event offers industry chance to partner with UKAEA on ITER investment

Published 19 January 2018
From:
UK Atomic Energy Authority
https://www.gov.uk/government/news/ukaea-launches-national-fusion-technology-platform

More than 80 delegates from key stakeholders across the UK nuclear sector have heard details of multi-million-pound contracts from ITER that they can target with help from UKAEA after the Government’s recent £86 million investment in UKAEA at Culham.

John Devine, head of exports and investment on the civil nuclear team at the Department for International Trade, kicked off the event at Corpus Christi College, Oxford, on Tuesday 16 January by saying he was confident in UKAEA’s expertise, capability and record, before adding that the event represented an “opportunity for UK technologies and companies to get involved” and “take their expertise to the world.”

Ian Chapman, UKAEA CEO, outlined how the two investments – H3AT and FTF – would help in making commercial fusion a reality.

The first centre of excellence – named Hydrogen-3 Advanced Technology (H3AT) – will research how to process and store tritium and helps with ITER’s development.

Ian Chapman said:

The main purpose of H3AT is to looking forward to ITER. We want to partner with UK industry to make sure they win these contracts. This will allow the R&D to have other benefits as well as fusion, while these facilities will also help to train the next generation of people who will operate ITER.

Added to that was the Fusion Technology Facility (FTF) for developing thermal hydraulic tests for components under fusion conditions: for example in a vacuum, high heat flux, under a magnetic field. Partnering with UKAEA will support industry with a range of test and design capabilities, preparing them to bid for forthcoming major ITER contracts.

Ian Chapman commented:

We are extremely well placed – through using these processes in JET and the new facilities – to support the supply chain in its bidding for a wide range of projects.

Tom Greatrex, Chief Executive of the Nuclear Industry Association, added:

The level of Government investment seen with the £86 million National Fusion Technology Platform demonstrates the expertise, confidence and ability of staff at Culham in being at the cutting edge of research. As well as being a world leader in fusion research, we have a similar industrial capability which we have the opportunity to seize. There is a very real sense that the UK can make its mark on the world in helping to develop sustainable nuclear power for the future.

6.

ENERGY TECH

Model predicts scenarios for energy generation using nuclear fusion

by Staff Writers
Sao Paulo, Brazil (SPX) Feb 02, 2018

HTTP://WWW.SPACEDAILY.COM/REPORTS/MODEL_PREDICTS_SCENARIOS_FOR_ENERGY_GENERATION_USING_NUCLEAR_FUSION_999.HTML

Nuclear fusion, for the controlled and regular generation of electric power by converting hydrogen into helium and reproducing on a small scale what happens in our Sun (as well as other stars), is one of the foremost technological promises for the decades ahead.

Designed to reach parameters beyond the ones previously obtained in laboratory experiments, the reactor prototype called ITER - "the way" in Latin - is presently under construction in southern France. Its design capacity is for 500 megawatts, and the plan is to go live in 2025. The members of the ITER consortium are China, the European Union, India, Japan, Russia, South Korea and the United States. The cost of the megaproject is expected to surpass euro 20 billion.

ITER will is not intended to provide electricity to the grid, but it will be the first tokamak to produce net energy, i.e., more energy is released from fusion reactions than the amount of energy injected to heat the plasma. It will enable scientists to learn more about handling the multiple technical complexities of nuclear fusion, paving the way for machines that do indeed use it to supply electricity to the grid. The term tokamak comes from the Russian acronym for a toroidal chamber with magnetic coils.

For this plan to succeed, however, it will be crucial to ensure that the nuclear fusion process can become self-sustaining and to prevent losses of energy via electromagnetic radiation and of alpha particles - the atomic nuclei of helium made up of two protons and two neutrons -as these losses would allow the reactor to cool. Experimental results observed during the past 20 years have shown that the way in which fast ions (including alpha particles) are ejected from the plasma varies greatly from one tokamak to another. Until recently, no one understood which experimental conditions determined this behavior.

The problem has now been elucidated by Vinicius Njaim Duarte, a young Brazilian researcher who recently earned his PhD with support from the Sao Paulo Research Foundation - FAPESP in the form of a doctoral scholarship and a research internship abroad. Duarte is currently engaged in postdoctoral research at the Princeton Plasma Physics Laboratory (PPPL) in the US.

Duarte is the lead author of the article "Theory and observation of the onset of nonlinear structures due to eigenmode destabilization by fast ions in tokamaks" highlighted by the Journal Physics of Plasmas, a publication of the American Institute of Physics (AIP).

Duarte's research drew so much attention that at the largest US tokamak, DIII-D, developed and operated by General Atomics in San Diego, California, dedicated experiments were conducted to test the model he proposed. The results confirmed the model's predictions.

"Electromagnetic waves excited by fast particles in tokamaks can display sudden variations in frequency, known as chirping in the jargon. No one understood why this happened on some machines and not in others. Using complex numerical modeling and experimental data, Duarte showed that whether chirping occurs or not - and hence the nature of particle and energy losses - depends on the level of turbulence in the plasma confined in the tokamak, where nuclear fusion reactions take place. Chirping occurs if it isn't highly turbulent. With severe turbulence, there's no chirping," said physicist Ricardo Magnus Osorio Galvao, now director of Brazil's National Space Research Institute (INPE) and former Duarte's PhD supervisor at the University of Sao Paulo's Physics Institute (IF-USP).

To make the import of this discovery comprehensible, a number of points must be explained.

First, it bears recalling that the process in question is nuclear fusion - not nuclear fission, the process used in the world's existing nuclear power plants. In fission, the atomic nuclei of heavy elements, such as uranium 235, for example, split into nuclei of lighter elements - krypton and barium in this case. This fission releases energy, electromagnetic radiation, and neutrons that in turn split in a chain reaction that keeps the process going.

Nuclear fusion works differently. In this process, the atomic nuclei of lighter elements, such as the hydrogen isotopes deuterium (one proton and one neutron) and tritium (one proton and two neutrons), fuse to form nuclei of heavier elements - in this case, helium (two protons and two neutrons) - and release energy.

"For nuclear fusion to be possible, it's necessary to overcome the electrostatic repulsion between positive ions," Galvao explained.

"This only happens if the ionized gas [plasma] formed by the nuclei of the light elements is heated to extremely high temperatures, of the order of tens to hundreds of millions of degrees Celsius."

In ITER, for example, 840 cubic meters of plasma will be heated to 150 million degrees Celsius, over ten times the temperature of the Sun's core.

"At that kind of temperature, you reach energy breakeven: the energy released by the fusion reactions is sufficient to equal the energy required to heat the plasma," Galvao said.

The process takes place inside the toroidal chamber of a tokamak, a device invented in the 1950s by Soviet physicists Igor Yevgenyevich Tamm and Andrei Sakharov, who were inspired by an original idea of their colleague Oleg Lavrentiev. A torus is shaped like a doughnut or an inner tube. The solid contained by the surface is known as a toroid.

The nuclear fusion process develops as follows. A vacuum is produced in the chamber, which is then filled with gas. An electric discharge ionizes the gas, which is heated by high-frequency radio waves.

An electrical field induced in the toroidal chamber subjects the gas to an extremely intense current of order of 1 million amperes in the case of DIII-D, which heats the gas even further via the Joule effect. Still more energy is injected by electromagnetic waves until the temperature required to trigger nuclear fusion is reached. Even a small tokamak, such as the one installed at the University of Sao Paulo, reaches temperatures on the order of millions degrees.

"At these extremely high temperatures, the ions vibrate so strongly that they collide and overcome electrostatic repulsion," Galvao said.

"A powerful magnetic field confines the plasma flow and keeps it away from the vessel's walls. The highly energized alpha particles [helium nuclei] collide with other particles in the plasma, keeping it hot and sustaining the fusion reactions."

An analogy suggested by Galvao would be a bonfire made with damp wood, which will not catch fire easily at first but which flares up eventually after a certain temperature is reached, and the steadily more stable combustion produces enough energy to overcome the humidity. In the case of a plasma, it is said to reach the ignition point when alpha particles begin consistently feeding back into the process.

Control of turbulence
Among fusion's many advantages over fission is the fact that fusion involves a self-control mechanism: once the ignition point is reached, if this temperature level is significantly exceeded - in other words, if the plasma overheats - the reaction automatically slows down. Thus reactor meltdown, one of the most dangerous complications of accidents in power plants that use nuclear fission, could not happen in a nuclear fusion plant.

The problem - and we now return to Duarte's research - is that resonant interaction between alpha particles and waves present in the plasma can excite electromagnetic oscillations or even lead to the ejection of alpha particles. This can cause energy loss, plasma cooling and possible interruption of nuclear fusion. Understanding the causes of this problem and the factors that can prevent it is fundamental to ensuring the sustainability of the process and the use of nuclear fusion as a viable source of electricity.

"What Duarte found is that this outcome happens in a self-organized manner, with the production of chirping, if the plasma is not very turbulent. If turbulence is high, however, it doesn't," Galvao said [see below for an interview with Vinicius Njaim Duarte].

The crux of the problem is that in a highly turbulent fluid, there is no preferential direction, Galvao explained, offering another analogy to help illustrate his meaning.

"When you heat water slowly, you create a convection cell in the container. Hot water rises, and cold water sinks. This continues until all the water reaches boiling point," he said.

"The medium then becomes turbulent, the convection cell is destroyed, and the energy spreads indiscriminately in all directions. This also happens in a magnetically confined plasma. Its occurrence prevents the creation of a self-organized system that sustains an undesirable associated electromagnetic wave. There isn't enough coherence for waves to be generated. So the loss of energy that would end the fusion process doesn't occur."

"Duarte had already published a paper on this model during his PhD research, but no one had performed an experiment to control the level of turbulence and see if the model applied or not. This has now been done by General Atomics on DIII-D, specifically in order to test the model, which was proven by the result."

Experimental physicists already knew empirically how to induce higher or lower turbulence, but they did not know this would affect the spectral nature of waves associated with the structures of particles. Duarte's contribution consisted of identifying the key control mechanism and explaining why. In terms of technological applications, this helps establish optimal turbulence - enough to prevent self-organized particle and energy loss but not enough to have other undesirable effects on overall plasma confinement.

Until now, tokamaks have been used on the laboratory scale. ITER will be the first prototype of a tokamak capable of generating electricity efficiently by nuclear fusion. The use of controlled nuclear fusion is not uncontroversial, but according to its advocates, it is safe, can produce a practically unlimited amount of power, and does not create radioactive waste, as do fission reactors.

Research Report: "Theory and observation of the onset of nonlinear structures due to eigenmode destabilization by fast ions in tokamaks"

7. Nuclear fusion's clean energy dream meets budget reality — and San Diego's General Atomics sweats it out

San Diego Union Tribune

Rob NikolewskiContact Reporter

http://www.sandiegouniontribune.com/business/energy-green/sd-fi-generalatomics-magnet-20180130-story.html

Using nuclear fusion as a virtually unlimited source of energy has been a thrilling yet distant dream for more than six decades.

An expensive and incredibly complicated international project to determine if the fantasy can become reality is finally taking shape — and San Diego's General Atomics is in the midst of constructing what may be the single most important portion of the program.

The project is called ITER, pronounced "EAT-er," short for the International Thermonuclear Experimental Reactor. General Atomics is building an incredibly powerful magnet called the Central Solenoid that will be inserted into the middle of the ITER device.

"It's probably the world's largest and most complex science experiment ever undertaken," said John Smith, the program manager at General Atomics overseeing the solenoid's development.

But the overall ITER project has been plagued with delays and has run way over budget.

And even if successful, ITER will not directly result in the construction of a commercially viable power plant. Instead, the entire point of the project is to determine *if* fusion can theoretically become the awesome source of power its advocates say it can be.

In many ways, ITER is a multi-billion dollar physics gamble. And there is no guarantee the project will work.

The United States is one of seven international partners in ITER and is responsible for 9 percent of the project's costs.

The U.S. contribution has been estimated at about $4 billion, a figure that has caused some lawmakers on both sides of the political aisle on Capitol Hill to worry that the dollars devoted to ITER are squeezing out funding that could go to other areas of energy research.

With the Congress and the Trump administration preparing to hammer out a budget, funding for ITER is in jeopardy.

What that means for the construction underway at General Atomics is unclear but last month a committee from the National Academies of Sciences, Engineering and Medicine released a report warning any decision by the U.S. to withdraw from ITER "could isolate U.S. fusion scientists from the international effort."

What fusion energy means

Nuclear fusion is different than its cousin, nuclear fission. Fission splits the nuclei of atoms to create power. It's the process used in nuclear power plants like the now-shuttered San Onofre Nuclear Generating Station.

Fusion, on the other hand, replicates the same energy source as the sun and stars, causing hydrogen nuclei to collide and fuse into helium atoms, releasing tremendous amounts of energy. Fusion technology was key in the development of the hydrogen bomb.

What exactly is ITER?

The ITER project aims to accelerate the practical applications of fusion at warp speed.

But it will require a remarkable level of coordination — involving not just technological innovation but international cooperation.

There are seven partners in the ITER project — the European Union, the U.S., Russia, China, South Korea, Japan and India. The EU has a 45 percent stake in ITER, with the other six countries contributing 9.1 percent each.

Each country will contribute physical portions of the ITER facility, which is being constructed in the town of Cadarache, France.

If harnessed for energy purposes, scientists believe fusion could become a source of safe, non-carbon emitting and virtually inexhaustible energy.

“The beauty of fusion power is that the fuel is limitless,” Smith said. “It could supply earth with electricity for thousands of years.”

However, a running joke is that fusion reactors are always 30 years away. Although fusion power has been generated for short periods in the laboratory, scientists have wrestled with ways to develop commercial applications for more than six decades.

At the center of ITER is a doughnut-shaped fusion reactor called a tokamak — an acronym dubbed by Russian scientists who experimented with fusion years ago — where fusion reactions will take place.

In order to replicate what the sun does, a "burning plasma" needs to be achieved in the fusion process. Atoms from two hydrogen isotopes are heated while being squeezed by massively powerful magnetic fields.

ITER will not capture the energy it will produce as electricity, but it hopes to prepare the way for a machine that can.

And ITER's proponents say it will leave behind no high-level radioactive waste and will be safe.

"If you stop the magnetic field or stop heating the plasma, the whole reaction goes out," Smith said. "There's no way it can sustain and have a runaway like a Three Mile Island. That's impossible to have in a fusion reactor ... It is a safe, inherent energy source."

What General Atomics is building

An incredibly powerful magnet that has been called the heartbeat of the ITER facility is being built by General Atomics in a 60,000 square-foot warehouse in Poway.

It’s called the Central Solenoid (CS), which helps drive the plasma’s current, which in turn makes the tokamak work to generate fusion. The plasma temperature the CS assists in producing is breathtaking — 10 times greater than the sun.

“It is crazy to think about, isn’t it?” said Smith, who has spent 10 years on the CS project and most of his career on nuclear fusion.

Forty-five full-time employees at General Atomics work on the CS project, which started in 2011. Six 250,000-pound circular modules are being fabricated, each of them 7 feet tall and 14 feet wide and consisting of 3.6 miles of superconducting cable.

A seventh module will be built, Smith said, as “a spare.”

Each module will be shipped to the ITER facility in France, where they will be carefully stacked on top of each other. The first CS module will be ready to be transported in 2019 and the last one is expected to head to Europe in 2021, well in advance of the first scheduled operational test for ITER in 2025.

“We’re right on schedule, we’re meeting our milestones,” Smith said.

Will Congress and the Trump administration keep the money flowing?

The same cannot be said for the ITER project in its entirety.

Building the facility began a decade ago but the price tag for the project has blown past its original estimate of $5 billion. In 2015, the costs rose to about $16 billion and the latest estimate is $22 billion.

Continued participation in ITER will cost an additional $100 million to $125 million annually for more than two decades.

The costs have caused heartburn on Capitol Hill, which is not unprecedented. ITER funding was put on ice in 1998 but the U.S. rejoined the project in 2006.

Sens. Dianne Feinstein (D-California) and Lamar Alexander (R-Tennessee) approved cuts to ITER in 2016, citing an effort to boost science projects based inside the U.S.

This decision was carefully considered and absolutely necessary in order to make key investments in our national laboratories and universities," Feinstein said at the time.

U.S. funding for ITER was cut from $105 million to $50 million in 2017.

Under a proposal from the House of Representatives, ITER funding for fiscal year 2018 will be cut from $120 million to $63 million. The proposal in the Senate is even more draconian — it calls for ITER funding to be zeroed out in 2018.

No wonder that ITER's director-general, Bernard Bigot, was in Washington last month, talking up the project's benefits and urging the U.S. remain committed to ITER.

"If the U.S. does not provide the necessary funds in 2018, then there will be an impact on the entire project," Bigot told Reuters.

The position of the Trump administration is unclear. Last year it proposed a 20 percent cut to the Department of Energy's Office of Science, which funds basic research for programs like ITER but Bigot said he was told the Trump administration is reconsidering the issue.

If funding for the U.S. contribution is completely cut off, what would happen to the General Atomics portion of the project?

Smith said when the U.S. signed on to the ITER agreement, it pledged it would either fund or build the components for the CS — even if it pulled out of the project.

"If the U.S. chooses to violate that then I think they have significant problems (signing up for) any international science project in the future," Smith said.

Stanford professor Franklin Orr dealt with ITER funding as undersecretary for science and engineering at the U.S. Department of Energy during the Obama administration and while he understands the frustration of ITER's critics Orr said the U.S. should stick with the program.

“If we don’t deliver what we promised to deliver then we have to pay somebody else to do it anyway,” Orr said. “It is expensive, there’s no doubt about it but the international nature of it makes it worth investigating … so I’d stay in if I were king.”

ITER proponents acknowledge the project’s budget problems but insist Bigot, who took over two years ago, has turned things around. The director-general’s trip to Washington coincided with ITER declaring the project has reached the 50 percent completion mark.

“There’s been some misconceptions,” Smith said. “I think in the U.S. a lot of people think we’re just pouring money over to France. In reality that isn’t true. Ninety percent of the dollars the U.S. has appropriated though Congress is being spent here in the U.S.”

Will it all be worth it?

If ITER can speed developments leading to an era of mass adoption of fusion-energy power plants, the ramifications would be extraordinary, transforming the energy systems of developed and under-developed economies around the world.

But the “burning plasma” necessary for the project to work has never been created and even fusion’s proponents have said commercial applications may be — just as the industry joke said — at least 30 years away.

Standing on the work floor in Poway in front of one of the CS modules, the 55-year-old Smith said he thinks the ITER project will be a success but he also said he doesn't think commercial devices will be up and running by the end of his lifetime.

"A good fraction of the 25 years of my career has been working on fusion energy, so I am invested," Smith said. "I do want to see it succeed. I think it has great potential for the world ... If there's no risk there's not a reward. And there's no reward without a risk."

8. UK committee concludes advice on Euratom exit

29 January 2018
http://www.world-nuclear-news.org/NP-UK-committee-concludes-advice-on-Euratom-exit-29011801.html

The nuclear power industry presents "particular challenges" in the context of Brexit, the House of Lords EU Energy and Environment Sub-Committee says in a report published today.
In gathering evidence for the report - *Brexit: energy security, looking at implications for energy supply, consumer costs and decarbonisation* - the committee heard that the UK's ability to build future nuclear generation sites, including Hinkley Point C, is in doubt if access to specialist EU workers is curtailed. Failure to replace the provisions of the European Atomic Energy Community, also known as Euratom Treaty, by the time the UK leaves the EU could result in the UK being unable to import nuclear materials, it says.
EDF Energy told the committee that nuclear generation is a key component of the current and future energy mix in the UK, where eight nuclear power stations currently provide 20% of the country's electricity needs.
"Not only do nuclear power stations supply a significant amount of low-carbon electricity, but the continuity of that supply helps balance less predictable renewable sources, providing further assistance to the UK in meeting its decarbonisation objectives," the report says.

It concludes that the Euratom Treaty is currently vital to the functioning of nuclear energy generation in the UK. It says: "Failure to replace its provisions by the point of withdrawal could result in the UK being unable to import nuclear materials and have severe consequences for the UK's energy security."

Safeguarding

Currently, the UK meets its safeguarding requirements through Euratom, as Euratom provides safeguarding inspections for more than 100 UK facilities (including non-power-producing nuclear facilities). In 2014 there were about 220 inspections, involving 1000 person-days of Euratom effort, according to the report.

"To maintain energy security it will be crucial to establish a domestic safeguarding regime that satisfies IAEA requirements by the time the UK leaves Euratom," it says. It adds, "We are encouraged" that both the government and the Office for Nuclear Regulation (ONR) "recognise the urgency of this".

Euratom's safeguarding standards are higher than those required by the UK's international obligations, the report notes. "It will be difficult for the government to deliver on its commitment to maintain Euratom's standards at the point of withdrawal," it says. The "first priority" should therefore be to ensure compliance with the UK's International Atomic Energy Agency (IAEA) obligations, it says.

It will be challenging for the ONR to recruit and train sufficient safeguarding inspectors by the time the UK withdraws from the Euratom Treaty, the report says. "We urge the government to provide any support possible and to consider what contingency measures may be required," it says.

The UK will need to establish new Nuclear Cooperation Agreements (NCAs) in order to maintain its existing nuclear supply chains, the report says. The UK currently trades nuclear materials with many other countries and the government should prioritise developing new NCAs with those with which nuclear trade would otherwise be illegal, such as the USA, Canada, Japan and Australia, it adds.

"It is vital that the government makes progress on developing new NCAs quickly. Given that these negotiations can only begin after the UK has satisfied the IAEA with regard to its safeguarding regime, it is essential for the Government to reach an agreement with the IAEA as soon as possible," it says.

The government must ensure that its nuclear trade agreements allow the movement of nuclear material and equipment in a timely fashion and at reasonable cost, it adds.

Nuclear R&D

The Joint European Torus (JET), located at Culham, Oxfordshire, is Europe's largest nuclear fusion device, enabling research into fusion power as an energy source. It is collectively used by more than 40 European laboratories. Its work is carried out within the framework of the EUROfusion Consortium, and it receives funding from the European Commission through the Euratom research and training programme.

JET's successor will be ITER, the International Thermonuclear Experimental Reactor, which is under construction in France. Europe is funding nearly 46% of the construction costs, with the remaining costs being split between China, India, Japan, Korea, Russia and the USA.

The report says: "The UK has benefited substantially from EU nuclear research programmes, contributing to its status as a world leader in nuclear research and development. It would be to the benefit of both the UK and the EU to maintain those research connections post-Brexit. We welcome the government's commitment to continuing to fund nuclear research in the UK, whether or not EU funding is maintained."

The committee recommends that the government "looks to maintain the post-Brexit viability" of JET, and ensures that the UK is able to participate in ITER despite its withdrawal from Euratom.

Future arrangements

A form of associate membership of Euratom could be a means of maintaining nuclear research and development collaboration with the EU, the report says. However, in the form currently held by non-EU Member State Switzerland, it would not address the issues raised by the UK's departure that are critical to energy security, it adds.

"The risk posed to the UK's energy security if the safeguarding measures currently provided by Euratom are not replaced in time means that there is a distinct need to avoid a cliff-edge in relation to Euratom. It is therefore crucial for the government to ensure that contingency arrangements are in place and ready to be activated if required," the report says. "The government should engage with industry regarding such arrangements as early as possible, in order to reduce commercial uncertainty."

It also notes that the UK's membership of Euratom is "legally distinct" from its EU membership, and that in the Prime Minister's Article 50 notification letter of 29 March 2017 a separate notification was made in respect of the country's withdrawal from Euratom.

"This suggests that separate transitional arrangements may also be possible, if they are needed in order to mitigate the risk of a cliff-edge. We therefore call on the government to review and report to Parliament on the possibility of a Euratom-specific transition period separate from the wider Brexit process," it says.

Researched and written
by World Nuclear News

9.- TAE Technologies pushes plasma machine to a new high on the nuclear fusion frontier

BY ALAN BOYLE on February 10, 2018 at 10:40 am

https://www.geekwire.com/2018/tae-technologies-pushes-plasma-machine-new-high-fusion-frontier/

TAE Technologies, the California-based fusion company backed by Microsoft co-founder Paul Allen, said its latest and greatest plasma generator has exceeded the headline-grabbing performance of its previous machine.

“This announcement is an important milestone on our quest to deliver world-changing, clean fusion energy to help combat climate change and improve the quality of life for people globally,” Michl Binderbauer, the company’s president and chief technology officer, said in a news release. “This achievement further validates the robustness of TAE’s underlying science and unique pathway.”

The $100 million machine, which went into operation less than a year ago, has been christened “Norman” in honor of physicist Norman Rostoker, the late founder of TAE (formerly known as Tri Alpha Energy). It takes the place of TAE’s C-2U plasma generator, which maintained high-temperature plasma rings in confinement for a record-setting 5 milliseconds back in 2015. Over the course of more than 100,000 experiments, the maximum confinement time eventually went even longer, to 11.5 milliseconds.

TAE said that the C-2U experiment checked off half of what's called the "Hot Enough, Long Enough" requirement — that is, demonstrating that a high-temperature plasma could be held in confinement long enough to sustain a nuclear fusion reaction. Such a reaction could take advantage of the same process that powers the sun to produce abundant, relatively cheap, relatively clean energy.

Just as the C-2U machine met the "Long Enough" standard, the Norman machine is making progress on the "Hot Enough" standard. After 4,000 experiments, TAE said the temperature of Norman's plasma has reached a high of nearly 20 million degrees Celsius (35.5 million degrees Fahrenheit).

That's almost twice as hot as C-2U's top temperature, and hotter than the temperature of the sun's core (which is estimated at 15 million degrees C, 27 million degrees F).

TAE attributed its rapid progress to its collaboration with Google on machine-learning simulations of plasma physics. The company is also taking advantage of a U.S. Department of Energy supercomputer program to boost its data-processing resources.

There's still has a long way to go. TAE's research team is aiming for a hydrogen-boron fusion reaction, which is cleaner than the typical deuterium-tritium reaction but more difficult to achieve. That means the target plasma temperature will eventually have to reach on the order of 3 billion degrees C, which will require building a successor to Norman and conducting years of follow-on experiments.

Despite the challenges ahead, TAE Technologies CEO Steven Specker said he was heartened by the latest achievement.

"It is profound to see TAE's scientific innovations bear out in Norman's performance," Specker said in the news release. "Our remarkable progress signals the reality of a future powered by fusion energy, and hydrogen-boron is as safe and clean a fuel source as you can find. It's a win-win for us all."

TAE's approach to fusion involves shooting "smoke rings" of high-energy plasma at each other within a magnetic confinement chamber, with neutral beams directed into the chamber to improve plasma stability. In a recent interview, TAE's Binderbauer told GeekWire that the technologies under development could be used for applications other than power generation.

"There's a medical application that's particularly interesting that we've started," he said, "and we've enabled that because we've gotten these beams to reactor-level performance already."

TAE says it has attracted $500 million in investment for private-sector fusion research over the past 20 years. In addition to Allen's Vulcan Capital, institutional investors include the Rockefeller family's Venrock venture capital firm and Rusnano, a Russian investment firm.

Other privately funded fusion ventures include Helion Energy in Redmond, Wash., which has won backing from tech billionaire Peter Thiel's Mithril investment firm; and General Fusion, which is headquartered in Burnaby, B.C., and counts Amazon's billionaire founder, Jeff Bezos, among its investors.

Those all come in addition to research efforts backed by government and academic funding, such as the multinational $20 billion ITER experimental reactor under construction in France, and the $1.1 billion Wendelstein 7-X stellarator in Germany.

For what it's worth, the Joint European Torus, or JET, has achieved plasma temperatures of around 100 million degrees C (180 million degrees F). And for just an instant at a time, Europe's Large Hadron Collider can create quark-gluon plasma at temperatures in excess of 5 trillion degrees C (9 trillion degrees F).

10. **OUT OF THIS WORLD** | Earth, Space and Everything In-Between - a daily journey through weather, space and science with meteorologist/science writer Scott Sutherland

Meet the scientists who want to harness the power of the Sun

https://www.theweathernetwork.com/news/articles/fusion-power-scientists-want-to-power-the-world-for-a-million-years/84704/

Scott Sutherland
Meteorologist/Science Writer
Thursday, February 8, 2018, 10:06 AM - Fusion is the power source of the future, according to science fiction, but did you know that scientists have been working on this for decades, and are drawing ever closer to harnessing the power of the Sun?

When we look up into the sky, and see the Sun burning brightly during the day, or the stars twinkling at night, we are seeing the products of fusion. Each of these stars, our Sun included, is an immense ball of mostly hydrogen gas, and the weight of the star crushes all that hydrogen down towards the middle, where temperatures reach somewhere around 15 million degrees Celsius. These incredible temperatures cause the hydrogen atoms to fly around so fast that they slam into one other with enough force that they fuse, producing an atom of helium, along with some energy.

A star like our Sun converts roughly 600 million tonnes of hydrogen into helium every second. With just one gram of hydrogen containing 602,300,000,000,000,000,000,000 atoms, when tally everything up, the little bit of energy released by each pair of atoms fusing turns into A LOT OF ENERGY. This energy is absorbed by the outer layers of the Sun, turning them into churning circulations of hydrogen, and this outward force keeps the star from collapsing in on itself. The energy that reaches the "surface" of the Sun escapes into space, providing us with light and heating the daylight side of our planet.

Now, if we could harness just a fraction of that energy, we would never need another source of energy, ever.

We can't bring a star down to Earth, of course, or even a piece of one, but what if we could safely mimic the way it generates energy?

This is the story behind the new documentary film, ***Let There Be Light***, co-directed by Mila Aung-Thwin and Van Royko, which made its Canadian debut at Toronto's 2017 Hot Docs Festival.

11. 50 YEARS AGO

PHYSICS,
TECHNOLOGY,
SCIENCE & SOCIETY

50 years on, nuclear fusion still hasn’t delivered clean energy

Excerpt from the February 17, 1968 issue of *Science News*

BY

MARIA TEMMING
7:00AM, FEBRUARY 8, 2018
https://www.sciencenews.org/article/50-years-nuclear-fusion-still-hasnt-delivered-clean-energy

Power within 30 years

Controlled thermonuclear fusion is moving so well that full-scale development could begin within five years, says Dr. David J. Rose....It might take 20 to 30 years beyond that before fusion could move into the power grid, though, he predicts. — *Science News*, February 17, 1968

Update

Governments and private-sector start-ups are still trying to wrangle thermonuclear fusion — the process that lights up stars and ignites hydrogen bombs — for clean energy, with limited progress (*SN: 2/6/16, p. 18*). One of the biggest ongoing projects is ITER in France, an international effort to build the first magnetic fusion reactor that pumps out more energy than it consumes. ITER plans to flip on the machine in 2025. Optimistic estimates put the first fusion power plants on the grid no sooner than 2040.

12. Will Brexit damage the UK's nuclear fusion prospects?

13 Feb 2018

Hailed by some as the future of clean energy, nuclear fusion is an exciting and promising area of research supported in the UK by the Atomic Energy Authority (UKAEA) – an organisation within the UK government responsible for the establishing the UK as a leader in sustainable nuclear energ https://www.soci.org/news/general-news/uk-atomic-energy-authority

Its core mission is for the commercial development of nuclear fusion power, a feat yet be to achieved, with research still ongoing into a feasible, large-scale reactor to convert energy from nuclear fusion into electricity.

An untapped source
Nuclear fusion occurs between two or more charged particles during a high-energy collision, with the resulting reaction producing a large amount of energy that could, at least theoretically, be converted into electricity. This reaction is only possible at extremely high temperatures and pressures, and is the process the Sun uses to generate energy.

Here on Earth, nuclear fusion is difficult to replicate, with researchers struggling to match the energy produced with the high amounts of energy needed to start the reaction, in order for it to become a feasible form of energy to power the world.

To date, the largest successful nuclear fusion reactor is the result of the Joint European Torus (JET), managed by the UKAEA at the Culham Science Centre, Oxford, UK, and used by more than 40 other European research laboratories.

Hosted at the centre since its conception in 1973, the EU project has produced the only operational reactor that can generate energy from nuclear fusion.

The JET is a tokamak – a device designed around the centrally placed fusion plasma, a fourth fundamental state of matter after solid, liquid, and air, that does not exist freely on Earth, containing the charged particles essential for nuclear fusion to occur.

Using strong magnetic fields, the tokamak confines the plasma to the shape of a torus (left) within a vacuum vessel. The plasma must be kept in this shape or it will cool and not meet the temperature needed for nuclear fusion.

Credit: Wikimedia Commons
Although other possibilities are still being explored, the tokamak is the leading candidate for a commercially viable nuclear fusion reactor and its design is the basis for JET's successor.

Making history
In 2025, the International Thermonuclear Experimental Reactor (ITER) will run its first experiment, and if successful will be the world's largest operating nuclear fusion reactor – ten times the size of any other in the world, producing upwards of 500MW of power.

A collaborative effort between 35 nations – China, India, Japan, Korea, Russia, the US, and all 28-member states of the EU – the ITER is the EU's successor project to JET. Based in Provence, southern France, the ITER is self-championed as 'one of the most ambitious energy projects in the world today'.

By 2025, ITER will produce its first plasma, later adding tritium and deuterium – a combination with an extremely low energy barrier – in 2035 to generate energy. If successful, the work on the ITER will confirm the feasibility of nuclear fusion as a large-scale, carbon-free energy source.

Future uncertainty
But with Brexit on the horizon, many have questioned the likelihood of the UK's participation in the project, despite the UKAEA's essential work in supporting the success of JET and continued commitment to investing in the project.

Director of ITER, Bernard Bigot, has said his concerns lie with the extension of Joint European Torus (JET) – ITER's predecessor which is due to end this year. 'If JET ends after 2018 in a way that is not coordinated with another global strategy for fusion development, clearly it will hurt ITER's development,' he said. 'For me it is a concern.'

Creating a new base for training and research would be costly, and is unlikely to be favoured, and those involved in Euratom, the EU's atomic energy community and main source of JET funding, are now worried that the seven-year gap between the projected end of funding to JET and the first experiment of ITER may damage the latter's prospects of success.

In a statement on the future of JET, the UK government said: 'The UK's commitment to continue funding the facility will apply should the EU approve extending the UK's contract to host the facility until 2020.'

With hopes for JET's funding to continue until at least 2023, and the UK government announcing its intentions to leave Euratom last year, the future of the UK's ability to compete in the nuclear sector rests on the progress of Brexit negotiations in the coming months.

By Georgina Hines

13. Green light for next Darlington refurbishment

19 February 2018
Ontario Power Generation (OPG) can proceed with the refurbishment of Darlington unit 3 after receiving the go-ahead from the province's Ministry of Energy. Refurbishment of Darlington unit 2 has now passed the half-way mark.
http://www.world-nuclear-news.org/C-Green-light-for-next-Darlington-refurbishment-1902187.html

Darlington 3 will be the second of the plant's Candu units to undergo refurbishment in a project that will enable the 3512 MWe plant to continue operations until 2055. All four units are to be refurbished in a phased CAD 12.8 billion ($9 billion) project which is scheduled for completion by 2026.

"The government took a phased approach to Darlington refurbishment, with each unit requiring individual approval to proceed," OPG president and CEO Jeff Lyash said. "The go-ahead to move forward with the next unit is a testament to the hard work and dedication of the Darlington Refurbishment team."

Ontario's electricity generation was 90% free of greenhouse gas emissions in 2016, and its 2017 long-term energy plan, published in October, recognises the refurbishment of existing nuclear power plants as the most cost-effective option for meeting the province's baseload generation needs. Nuclear power - from OPG's Darlington and Pickering, and Bruce Power's Bruce plant - supply enough power to meet about 60% of the province's electricity needs.

Ten Candu units are to be refurbished between 2016 and 2033 - four at Darlington and six at Bruce. The Pickering nuclear power plant will continue to operate until 2024 to provide baseload electricity during the Darlington and initial Bruce refurbishments. Bruce Power has already begun its Life Extension Project, with the first major component replacements scheduled to begin on unit 6 in 2020.

Bruce Power President and CEO Mike Renchek said the two companies had proved that nuclear refurbishment projects could be delivered efficiently and effectively.

"The two largest infrastructure projects in Canada are the Bruce Power and OPG refurbishments, and both remain on-time and on-budget," he said. The two companies will continue to share resources and implement lessons learned from their projects, he added.

Refurbishment of Darlington unit 2 formally began on 14 October 2016 after six years of planning, and will take some 40 months to complete. The project passed the half-way mark on 15 February and remains on time and on budget, OPG said.

All 960 end fittings from the reactor's fuel channels have now been removed from the reactor core, enabling work to begin on the removal of pressure tubes. This will be achieved using remotely controlled automated retooling platforms. Removal and replacement of the reactor's 480 calandria tubes, 480 pressure tubes and 960 feeder pipes is the largest work package in the refurbishment project.

The planned refurbishment outage sequence at Darlington calls for refurbishment of unit 2 to be completed before the start of work on unit 3, to allow the implementation of lessons learned. OPG's schedule sees work beginning on unit 3 in February 2020, on unit 1 in July 2021 and unit 4 in January 2023.

Glenn Thibeault, Ontario's minister of energy, said the Darlington refurbishment would ensure that "reliable" nuclear energy continued to be the "backbone" of the province's generation fleet.
"This multi-phase project will continue to boost economic activity across Ontario, create jobs and secure a clean supply of affordable electricity for the future," he said.
Investments in refurbishing Ontario's nuclear fleet provide a strategic advantage for the province, Canadian Nuclear Association President and CEO John Barrett said.
"Our nuclear generating stations provide low-cost electricity, paramount to job creation and economic growth, while simultaneously allowing the province to continue to offset harmful greenhouse gas emissions," he said.
Researched and written
by World Nuclear News

14. Restart of Genkai 3 moves closer with fuel loading

16 February 2018
Kyushu Electric Power Company today began loading fuel into the core of unit 3 at its Genkai nuclear power plant in Japan's Saga prefecture. The reactor, together with unit 4, is expected to be restarted later this year.

http://www.world-nuclear-news.org/C-Restart-of-Genkai-3-moves-closer-with-fuel-loading-1602184.html

Under Japan's reactor restart process, plant operators are required to apply to the Nuclear Regulation Authority (NRA) for: permission to make changes to the reactor installation; approval of its construction plan to strengthen the plant; and, final safety inspections to ensure the unit meets new safety requirements. Operators are required to add certain safety-enhancing equipment within five years of receiving the NRA's approval of a reactor engineering work programme.

Kyushu submitted applications to Japan's Nuclear Regulation Authority (NRA) in July 2013 to restart Genkai 3 and 4, which have been offline since December 2010 and December 2011, respectively. In January 2017, the NRA confirmed the two 1180 MWe pressurised water reactors meet new regulatory standards.

The Saga prefectural governor gave his approval in April for the restart of the units, following the prefectural assembly's adoption of a resolution permitting their restart.

A group of some 230 residents from Saga and neighbouring Fukuoka Prefecture filed a lawsuit with the Saga District Court in July 2011. They claimed the safety of the Genkai plant is not secured. Kyushu, they said, had inadequate measures in place against earthquakes at the plant and a serious accident could occur due to degradation in pipe work. However, in a ruling last June, the court said it had found no issues with the plant's earthquake resistance or steps taken against serious accidents. It said there was no specific danger of radiation exposure at the plant.

Following NRA pre-operation inspections of the units to confirm that the safety countermeasure equipment complies with the approved construction plan at the Genkai plant, Kyushu is now loading fuel into unit 3 ahead of its restart.

In a statement, Kyushu said: "We continuously place the highest priority on safety, responding to inspections by the government sincerely and politely, and make our every effort to ensure security for the restart of our nuclear power stations."

Kyushu submitted a decommissioning plan for Genkai 1 to the NRA in December 2015. It has yet to decide whether to apply to restart unit 2.

Of Japan's 42 operable reactors, five have so far cleared inspections confirming they meet the new regulatory safety standards and have resumed operation. These are: Kyushu's Sendai units 1 and 2; Shikoku's Ikata unit 3; and Kansai's Takahama units 3 and 4. Another 19 reactors have applied to restart.

Earlier this week, Kansai completed loading fuel assemblies into the core of unit 3 at its Ohi nuclear power plant in Fukui Prefecture. The utility plans to return both units 3 and 4 at the plant to commercial operation by mid-2018.

Researched and written
by World Nuclear News

15. Holtec and GEH team up on advancing SMR-160

15 February 2018

Holtec International and GE Hitachi Nuclear Energy (GEH) are to collaborate on accelerating the commercialisation of Holtec's SMR-160 small modular reactor (SMR). Their cooperation will initially include nuclear fuel development and control rod drive mechanisms.

http://www.world-nuclear-news.org/NN-Holtec-and-GEH-team-up-on-advancing-SMR-160-1502184.html

Under a memorandum of understanding, GEH, Global Nuclear Fuel (GNF), Holtec and SMR Inventec LLC (SMR LLC) have agreed to enter into a "procompetitive collaboration" to progress the SMR-160.
GNF, a GE-led joint venture with Hitachi and Toshiba, is primarily known as a supplier of boiling water reactor fuel.
SMR LLC is a wholly-owned subsidiary of Holtec established in 2011 to manage the development of the SMR-160.
The cooperation between the four companies will initially include nuclear fuel development supported by GNF and control rod drive mechanisms designed by GEH, and may later extend to other areas.

Holtec president and CEO Kris Singh said, "This collaboration will ensure the SMR-160 supply chain, to deliver and fabricate critical SMR-160 technologies and components, including at our new Advanced Manufacturing Division in Camden, New Jersey.

GNF CEO Amir Vexler added: "We believe that our experience with boiling water reactor fuel lends itself quite well to the design features of the SMR-160."

Holtec's 160 MWe small modular reactor uses low-enriched uranium fuel. The factory-built reactor's core and all nuclear steam supply system components would be located underground, and the design incorporates a wealth of features including a passive cooling system that would be able to operate indefinitely after shutdown. No active components, such as pumps, are needed to run the reactor, which does not need any on-site or off-site power to shut down and to dissipate decay heat. The SMR-160 is planned for operation by 2026.

SMR LLC submitted a proposal to the US Department of Energy on 31 January with support from GEH and GNF, among others, in response to a funding opportunity announcement. This is for a test programme to investigate and validate the performance of the passive safety features of SMRs. Under the proposal, GEH and GNF will support phenomena assessments, scaling analyses, safety analysis system code assessment, and benchmarking and identification of recommended experimental tests.

GEH and Holtec said the project "would yield a uniquely configurable set of testing platforms" to demonstrate passive safety system performance, accelerate the SMR-160 and other SMR designs to market and help licence them with the US Nuclear Regulatory Commission (NRC) and international regulators.

In July last year, Holtec signed a teaming agreement with Canada's SNC-Lavalin to collaborate in the development of the SMR-160. Under the agreement, SNC-Lavalin - the parent company of Candu Energy - will provide Holtec with a range of nuclear engineering services, including supporting the licensing of the SMR-160 reactor.

Holtec has previously secured engineering, design and qualification support for its work on the SMR-160 from the Shaw Group and URS Corporation, and has a strategic alliance with utility PSEG Power, operator of three nuclear units at Salem and Hope Creek in New Jersey. In August 2015, Mitsubishi Electric Power Products Inc signed a long-term partnership agreement with Holtec to develop the instrumentation and control systems for the SMR-160.

The project was selected by the US Department of Energy in 2012 as one of three SMR projects to be demonstrated potentially at its Savannah River site in South Carolina. The NRC is carrying out pre-application activities on the reactor design.

Researched and written
by World Nuclear News

16. Fusion breakthroughs among highlights of the Department of Energy’s research milestones during the past 40 years

By
John Greenwald
February 16, 2018

https://www.pppl.gov/news/2018/02/fusion-breakthroughs-among-highlights-department-energy’s-research-milestones-during

The U.S. Department of Energy’s (DOE) Office of Science, the largest U.S. supporter of basic research in the physical sciences, celebrated the 40th anniversary of its founding in 2017. To mark the 40th anniversary of Office of Science support for the country’s national laboratories and basic research at universities and private industry, the DOE has compiled 40 milestone papers(link is external) that represent what the Department calls “a cream-of-the crop selection that has changed the face of science.”

Among the 40 Office of Science milestones: four landmark papers are on breakthroughs in the development of fusion energy. Two are from PPPL, one is from the DIII-D National Fusion Facility with which PPPL collaborates, and one is by Nat Fisch, a PPPL physicist and Princeton University professor, who based the paper on his doctoral dissertation at MIT.

“These papers highlight the substantial progress in fusion energy and plasma physics in the DOE program,” said Michael Zarnstorff, deputy director for research at PPPL. “This research has advanced our fundamental understanding and established the path to make fusion energy a reality.”

Here are the four major papers, which represent 10 percent of the DOE's "40 Years of Research Milestones," in reverse chronological order:

1994 – PPPL physicists report the successful first use (link is external) of a high-power mix of deuterium and tritium to produce fusion energy on the Tokamak Fusion Test Reactor (TFTR). Shortly after the paper appeared, the reactor produced an unprecedented 10.7 megawatts of fusion power. The deuterium-tritium mix will serve as fuel for future tokamaks including ITER, the international experiment under construction in France to demonstrate the practicality of fusion power.

1990 – For fusion to take place in tokamaks, researchers must calm the randomly fluctuating turbulence produced by plasma that is far hotter than the core of the sun.At DIII-D, which General Atomics operates for the DOE in California, physicists discover that changing the shearing of the flow(link is external) in the plasma can break up turbulent eddies that cause heat and particles to leak out. The discovery produced agreement between experiments and key theoretical predictions and allows plasmas to reach the superhot temperatures that fusion requires and that will be crucial for the success of ITER.

1989 – Research conducted on the Princeton Beta Experiment (PBX-M) at PPPL demonstrates how to measure the helical magnetic field(link is external) that confines the plasma during fusion experiments. The magnetic field is given helical form by current induced in the plasma. Researchers measured the helical angle inside the hot plasma by interpreting the light emitted by atoms injected into the plasma. Today, the technique allows physicists to tailor the magnetic field to maximize fusion performance.

1978 – The current that creates the helical magnetic field in tokamaks must be sustained during experiments. In the early days of tokamaks, the current could only be sustained for short time periods. In his landmark paper, Nat Fisch, drawing on his dissertation(link is external) as a doctoral student at MIT and overturning the conventional thinking of power dissipation in plasma, suggested an energy-efficient method for maintaining this current using radio frequency waves. Fisch, now a professor in the Princeton University Department of Astrophysical Sciences, is director of graduate studies for the Program in Plasma Physics that brings graduate students to study and work with scientists at PPPL.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas — ultra-hot, charged gases — and to developing practical solutions for the creation of fusion energy. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov(link is external).

17. Smooth sailing: PPPL develops an integrated approach to understand how to better control instabilities in an international fusion device

By
Raphael Rosen
February 12, 2018
https://www.pppl.gov/news/2018/02/smooth-sailing-pppl-develops-integrated-approach-understand-how-better-control

A key goal for ITER, the international fusion device under construction in France, will be to produce 10 times more power than goes into it to heat the hot, charged plasma that sustains fusion reactions. Among the steps needed to reach that goal will be controlling instabilities called "neoclassical tearing modes" that can cause magnetic islands to grow in the plasma and shut down those reactions.

Fusion, the reaction that powers the sun and most stars, is the fusing of light elements that generates massive amounts of energy. Scientists seek to replicate fusion on Earth, creating a "star in a jar," for a virtually inexhaustible supply of power to produce electricity.

Outlining a direction for the control of tearing modes has been physicist Francesca Poli of the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL). She and coauthors recently published findings in the journal *Nuclear Fusion* that describe an approach that for the first time simultaneously simulates the plasma, the magnetic islands, and the feedback control from waves that provide so-called electron cyclotron heating and current drive.

These waves, which accelerate the electrons gyrating along magnetic field lines in the plasma in fusion devices called "tokamaks," can deposit energy into the islands and should have the ability to suppress or stabilize tearing modes in the ITER device. "Basically, you are trying to shoot the beam of electron-cyclotron waves inside the island to replace current that has been depleted from the island," Poli said. "If you shoot inside the island, that's okay. If you shoot outside the island, that's not okay. The current from the electron-cyclotron waves has to be aligned, within some uncertainty, with the island. The simulations we performed can determine the maximum misalignment that can be tolerated and under which conditions experiments should be run."

Poli conducted the research on PPPL computers running TRANSP, the PPPL-developed code that physicists around the world employ to analyze and predict fusion experiments. Results showed that simulations are generally most helpful when they model the plasma in an integrated manner. For example, rather than depict a magnetic island in isolation, simulations should take into account what happens to the surrounding plasma both when the island grows and after the application of radio waves to produce the electron-cyclotron heating. Only by using a more integrated model can scientists determine under which conditions the island stabilization will be successful.

Coauthors of the paper presenting the findings were Eric Frederickson and Nicola Bertelli of PPPL; Mark Henderson and Sun Hee Kim of the ITER Organization; Emanuele Poli of the Max Planck Institute for Plasma Physics, Germany; and Daniela Farina and Lorenzo Figini of the Institute of Plasma Physics, Italy. Support for this work comes from the DOE Office of Science and the ITER Organization.

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18. Lithium — it's not just for batteries: The powdered metal can reduce instabilities in fusion plasmas

By
Raphael Rosen
February 5, 2018
https://www.pppl.gov/news/2018/02/lithium-—-it's-not-just-batteries-powdered-metal-can-reduce-instabilities-fusion

You may be most familiar with the element lithium as an integral component of your smart phone's battery, but the element also plays a role in the development of clean fusion energy. When used on tungsten surfaces in fusion devices, lithium can reduce periodic instabilities in plasma that can damage the reactor walls, scientists have found.

The results, demonstrated by scientists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and collaborators on China's Experimental Advanced Superconducting Tokamak (EAST) found that lithium powder can eliminate instabilities known as edge-localized modes (ELMs) when used to coat a tungsten plasma-facing component called the "divertor" — the unit that exhausts waste heat and particles from plasma that fuels fusion reactions. If left alone, such instabilities can damage the divertor and cause fusion reactions to fizzle.

The results are good news for future devices that plan to use tungsten for their own divertors that are designed to work with lithium.

Past experiments with lithium powder on EAST have confirmed the metal's ability to eliminate or reduce the frequency and intensity of periodic bursts of ELMs that occur in the outer edge of plasmas that can damage the divertor. ELMs develop regularly when the plasma enters a high-energy state known as high-confinement mode, or H-mode, which holds heat within the plasma more efficiently. ELMs can also unleash large amounts of heat that damage the plasma-facing components and release eroded material that can enter the plasma and cool the fusion reactions.

During the past experiments, EAST's upper and lower divertors were coated with light and porous carbon rather than the heavy metal tungsten. "So, the question was whether lithium will have the same effect on tungsten walls as it does with carbon walls," said PPPL physicist Rajesh Maingi, lead author with Jiansheng Hu of the Institute of Plasma Physics at the Chinese Academy of Sciences (ASIPP) of a paper describing the results in the journal *Nuclear Fusion*.

The issue was in question because recent research on other doughnut-shaped tokamaks, such as the Axi-Symmetric Divertor Experiment-Upgrade (ASDEX-U) in Germany, have suggested that plasma-facing components made of tungsten actually reduce the ability of lithium coatings to control ELMs. Lithium was injected into ASDEX-U via large fast pellets, as compared with the lithium powder that was gravitationally injected into the EAST experiments.

In the recent experiments, researchers manipulated the plasma within EAST so that it exhausted its waste heat on the upper of the two divertors within the tokamak. Unlike the lower divertor, which was made of carbon, the upper divertor is fabricated from tungsten.

The results showed that lithium injected into plasma in contact with tungsten reduces ELMs just as much as lithium does when the plasma exhausts its heat on carbon. Physicists now have increased confidence that the techniques used to reduce ELMs in current fusion machines will be able to reduce ELMs in larger machines in the future, as long as they are designed to be compatible with lithium.

The research team noted that it became easier to eliminate ELMs as the experiments progressed, suggesting that elimination could require less lithium as time went on. Scientists would therefore like to find a way to regulate how much lithium is injected into the plasma, perhaps reducing the injection rate once the ELMs have disappeared to control the lithium inventory and optimize the performance of the plasma.

This research was funded by the DOE Office of Science together with the National Key Research and Development Program of China, the National Nature Science Foundation of China, and the National Magnetic Confinement Fusion Science Program of China. The team included scientists from PPPL, ASIPP, Johns Hopkins University, the Department of Applied Physics in China's Hunan University, Oak Ridge National Laboratory, and General Atomics.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas — ultra-hot, charged gases — and to developing practical solutions for the creation of fusion energy. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov

19. Integrated simulations answer 20-year-old question in fusion research

Study finds that turbulence competes in fusion plasmas to rapidly respond to temperature perturbations.

http://news.mit.edu/2018/integrated-simulations-answer-20-year-old-question-fusion-research-0216

Leda Zimmerman | Department of Nuclear Science and Engineering
February 16, 2018

To make fusion energy a reality, scientists must harness fusion plasma, a fiery gaseous maelstrom in which radioactive particles react to generate heat for electricity. But the turbulence of fusion plasma can confront researchers with unruly behaviors that confound attempts to make predictions and develop models. In experiments over the past two decades, an especially vexing problem has emerged: In response to deliberate cooling at its edges, fusion plasma inexplicably undergoes abrupt increases in central temperature.

These counterintuitive temperature spikes, which fly against the physics of heat transport models, have not found an explanation — until now.

A team led by Anne White, the Cecil and Ida Green Associate Professor in the Department of Nuclear Science and Engineering, and Pablo Rodriguez Fernandez, a graduate student in the department, has conducted studies that offer a new take on the complex physics of plasma heat transport and point toward more robust models of fusion plasma behavior. The results of their work appear this week in the journal *Physical Review Letters.* Rodriguez Fernandez is first author on the paper.

In experiments using MIT's Alcator C-Mod tokamak (a toroidal-shaped device that deploys a magnetic field to contain the star-furnace heat of plasma), the White team focused on the problem of turbulence and its impact on heating and cooling. In tokamaks, heat transport is typically dominated by turbulent movement of plasma, driven by gradients in plasma pressure.

Hot and cold

Scientists have a good grasp of turbulent transport of heat when the plasma is held at steady-state conditions. But when the plasma is intentionally perturbed, standard models of heat transport simply cannot capture plasma's dynamic response.

In one such case, the cold-pulse experiment, researchers perturb the plasma near its edge by injecting an impurity, which results in a rapid cooling of the edge.

"Now, if I told you we cooled the edge of hot plasma, and I asked you what will happen at the center of the plasma, you would probably say that the center should cool down too," says White. "But when scientists first did this experiment 20 years ago, they saw that edge cooling led to core heating in low-density plasmas, with the temperature in the core rising, and much faster than any standard transport model would predict." Further mystifying researchers was the fact that at higher densities, the plasma core would cool down.

Replicated many times, these cold-pulse experiments with their unlikely results defy what is called the standard local model for the turbulent transport of heat and particles in fusion devices. They also represent a major barrier to predictive modeling in high-performance fusion experiments such as ITER, the international nuclear fusion project, and MIT's own proposed smaller-scale fusion reactor, ARC.

To achieve a new perspective on heat transport during cold-pulse experiments, White's team developed a unique twist.

"We knew that the plasma rotation, that is, how fast the plasma was spinning in the toroidal direction, would change during these cold-pulse experiments, which complicates the analysis quite a bit," White notes. This is because the coupling between momentum transport and heat transport in fusion plasmas is still not fully understood," she explains. "We needed to unambiguously isolate one effect from the other."

As a first step, the team developed a new experiment that conclusively demonstrated how the cold-pulse phenomena associated with heat transport would occur irrespective of the plasma rotation state. With Rodriguez Fernandez as first author, White's group reported this key result in the journal *Nuclear Fusion* in 2017.

A new integrated simulation

From there, a tour de force of modeling was needed to recreate the cold-pulse dynamics seen in the experiments. To tackle the problem, Rodriguez Fernandez built a new framework, called PRIMA, which allowed him to introduce cold-pulses in time-dependent simulations. Using special software that factored in the turbulence, radiation and heat transport physics inside a tokamak, PRIMA could model cold-pulse phenomena consistent with experimental measurements.

“I spent a long time simulating the propagation of cold pulses by only using an increase in radiated power, which is the most intuitive effect of a cold-pulse injection,” Rodriguez Fernandez says.

Because experimental data showed that the electron density increased with every cold pulse injection, Rodriguez Fernandez implemented an analogous effect in his simulations. He observed a very good match in amplitude and time-scales of the core temperature behavior. “That was an ‘aha!’ moment,” he recalls.

Using PRIMA, Rodriguez Fernandez discovered that a competition between types of turbulent modes in the plasma could explain the cold-pulse experiments. These different modes, explains White, compete to become the dominant cause of the heat transport. “Whichever one wins will determine the temperature profile response, and determine whether the center heats up or cools down after the edge cooling,” she says.

By determining the factors behind the center-heating phenomenon (the so-called nonlocal response) in cold-pulse experiments, White’s team has removed a central concern about limitations in the standard, predictive (local) model of plasma behavior. This means, says White, that “we are more confident that the local model can be used to predict plasma behavior in future high performance fusion plasma experiments — and eventually, in reactors.”

"This work is of great significance for validating fundamental assumptions underpinning the standard model of core tokamak turbulence,” says Jonathan Citrin, Integrated Modelling and Transport Group leader at the Dutch Institute for Fundamental Energy Research (DIFFER), who was not involved in the research. “The work also validated the use of reduced models, which can be run without the need for supercomputers, allowing to predict plasma evolution over longer timescales compared to full-physics simulations,” says Citrin. “This was key to deciphering the challenging experimental observations discussed in the paper.”

The work isn’t over for the team. As part of a separate collaboration between MIT and General Atomics, Plasma Science and Fusion Center scientists are installing a new laser ablation system to facilitate cold-pulse experiments at the DIII-D tokamak in San Diego, California, with first data expected soon. Rodriguez Fernandez has used the integrated simulation tool PRIMA to predict the cold-pulse behavior at DIII-D, and he will perform an experimental test of the predictions later this year to complete his PhD research.

The research team included Brian Grierson and Xingqiu Yuan, research scientists at Princeton Plasma Physics Laboratory; Gary Staebler, research scientist at General Atomics; Martin Greenwald, Nathan Howard, Amanda Hubbard, Jerry Hughes, Jim Irby and

John Rice, research scientists from the MIT Plasma Science and Fusion Center; and MIT grad students Norman Cao, Alex Creely, and Francesco Sciortino. The work was supported by the US DOE Fusion Energy Sciences.

20. Looking ahead

"The world community around fusion is expanding"

K.D.

For the first time, the Fusion Power Coordinating Committee has convened outside of International Energy Agency (IEA) headquarters in Paris, gathering at ITER on 24 and 25 January. Since 1975, this IEA body has piloted strategically coordinated fusion research and science. Physicist Jean Jacquinot*, the newly elected Chair, tells us about the Committee's role and its strong links to ITER.

https://www.iter.org/newsline/-/2910

The Fusion Power Coordinating Committee (FPCC) is described as "a forum for the coordination of international science and research with regard to fusion." How does it operate?

The objective of the Fusion Power Coordinating Committee is to stimulate and rationalize R&D activities in fusion science and technology with an eye to the long term. The goal is the realization of fusion energy; the method is a step-by-step approach based on coordinated research activities that can be device-specific or cross-cutting. The Committee initiates, or promotes, R&D and cooperative experiments among participating IEA members and partner countries internationally.

Under the FPCC umbrella, for example, experiments are conducted on tokamak devices worldwide and the results are compared. This type of scaling activity is extremely valuable; in fact, it was just this type of coordinated experimentation that contributed to the dimensioning of ITER. We are continuing in this direction to support the ITER program and to plan in parallel for the steps after ITER. We don't just exchange words, but also hardware, people, and scientific results.

Why hold this year's meeting at ITER Headquarters?
ITER is a key device on the road to fusion energy and the Fusion Power Coordinating Committee is marshalling fusion community resources to contribute to its success. Our role is to identify the most urgent ITER needs in terms of scientific or technological issues and see how we can support their resolution. For this, we have a tool—the IEA Technology Collaboration Programmes.

Technology Collaboration Programmes operate in different areas of IEA activity. As part of the fusion portfolio there are Programmes in eight areas: tokamak cooperation; the environmental, safety and economic aspects of fusion power; materials, fusion reactor technology; plasma-wall interactions; reversed field pinch devices; spherical tori; and the stellarator-heliotron concept. The FPCC manages these Programmes.
The ITER Organization has been a contracting party since 2012 to the Programme on tokamak cooperation (CTP-TCP), with the ITER Science & Operations Department chairing the CTP-TCP Executive Committee from 2016 to this most recent meeting. This group looks in particular at issues related to the stability of the plasma, with experimental programs for example on the prediction and control of disruptions.

How does the work of the Technology Collaboration Programmes overlap with the topical groups of the International Tokamak Physics Activity (ITPA), which operates under the auspices of ITER?

It's true that the ITPA is also a framework for internationally coordinated fusion research activities, but it focuses on science issues only. There can be overlap between the areas of focus, but we are careful to make sure there is no duplication. You'll find that a good number of top scientists participate in both activities and that there is excellent understanding between the two groups.

There is one other major difference. Participants to the FPCC Technology Collaboration Programmes actually sign formal Implementing Agreements, which establish a contractual relationship between at least two IEA member countries or contracting parties. These agreements are multilateral technology collaboration mechanisms that permit the exchange of material, the exchange of personnel, and joint experimentation.

What were the highlights from the most recent meeting?

The level of cooperation around fusion issues is quite remarkable, and it is widening. It's no exaggeration to say that the world community around fusion is expanding. Originally, participation in IEA Technology Collaboration Programmes was limited to OECD nations, but the enlargement of membership is now encouraged. We have been joined by Costa Rica and Australia, as well as non-IEA countries like China, India and Russia.
Essentially all significant R&D in the tokamak fusion area is done through international collaboration: we identify issues, meet to discuss how we could respond, and then share our results.

The chairs of most Technology Collaboration Programmes were present at our most recent meeting, as well as a delegation of ITER scientists and other representatives of the members—about 30 people in all. The ITER Director-General also participated actively through a number of presentations, including one in which he identified the top ITER R&D needs. We then made detailed proposals for joint collaboration.

My role as Chair will now be to report to the Committee on Energy Research and Technology (CERT), which oversees technology forecasting and analyses, and the research, development, demonstration and deployment strategies for the IEA. Throughout the year I will keep in close contact with the Technology Collaboration Programme chairs to see how implementation is proceeding.

**Formerly Director of the Joint European Torus (JET) and Director of the French CEA's magnetic fusion research department (DRFC, today IRFM), Jean Jacquinot has been closely associated with ITER for the past quarter century. He is presently a scientific advisor to the French High Commissioner for Atomic Energy and Senior Advisor to the ITER Director-General.*

21. NFRI News

Vol. 18 January 2018

Outstanding progress in KSTAR for RMP-driven, ELM-crash suppressions

https://www.nfri.re.kr/eng/post/eng_news/40869

KSTAR has accomplished a world record-long (~34 sec) sustainment of high-confinement mode (H-mode) plasmas, while fully suppressing the edge- localized modes (ELMs) by resonant magnetic perturbations (RMP) [See Figure 1]. Since the sustained time scale of quasi-stationary ELM- suppression is comparable to the fueling-associated wall saturation time (~ 30 sec) in KSTAR, this elevates the confidence about the effectiveness of the planned RMP on steady-state, H-mode plasmas in ITER.

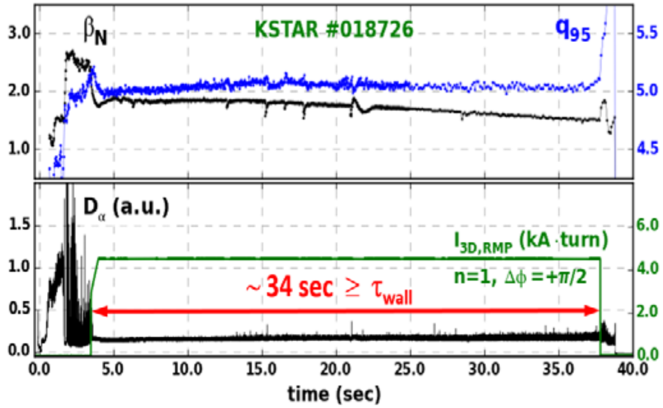

Figure 1. Demonstration of quasi-stationary sustainment (~34 sec; the longest ever) of edge- localized-mode (ELM) suppression using RMP in KSTAR (whose 3-row configuration is similar to what is planned for ITER).

Ever since the first n=1 RMP-driven, ELM-crash- suppression was discovered in 2011 [Y.M. Jeon et al, PRL (2012)], the KSTAR team has been actively investigating the underlying physics mechanism, as well as searching for the path to robust ELM-crash- suppression beyond ELM-mitigation. Indeed, for the last couple of years, KSTAR has made significant progress in both scientific and technological aspects.

Specifically, KSTAR has now established full ELM- crash-suppressions in a wide range of the safety factor at q_{95} = 3.4 ~ 6.4 (rather than being limited in a single value) using either n=1 or n=2 RMPs, satisfying a low edge collisionality (*~ 0.2), close to ITER-target plasmas. In addition to the well-known critical parameters (q_{95}, *, B-spectra), we have newly found the importance of highly shaped plasma (triangularity of ~ 0.6), while securing a semi-empirical prediction capability of RMP configurations necessary for ELM suppression. Overall, highly shaped plasmas appear quite resilient against mode-lockings in core, whose presence might have otherwise spoiled the influence of RMP at edge. Also, as long as core mode-locking is avoided, the increase of RMP is desirable to suppress the ELMs at edge. Thus, assuming that resonant components in an optimal RMP configuration should be configured i) maximally at the edge to control ELMs but ii) minimally in the core to avoid mode-locking, a semi-empirical prediction tool has been developed and confirmed to be in excellent agreement with experiments [Y. In et al, NF (2017)].

While exploring the critical onset conditions for ELM suppression, we have directly measured an evidence of bifurcation in the vicinity of $_{\perp,e}$ ~ 0 at pedestal top [See Figure 2], consistent with theory. Although the optimal 3-D configuration necessary for ELM suppression can be determined from single-fluid ideal MHDs without taking into account the edge plasma rotation, the transition from mitigation to suppression of ELMs certainly requires the two-fluid considerations, subject to electron rotation variations. In addition, we have demonstrated, for the first time, broadened divertor heat flux during RMP-driven ELM suppression, as well as during RMP-driven ELM mitigation, using intentionally misaligned 3-row RMPs whose configurations could be similarly conceived in ITER. This strongly suggests that ITER RMP system could be utilized to disperse the divertor heat flux without compromising the lifetime of materials associated with fatigues.

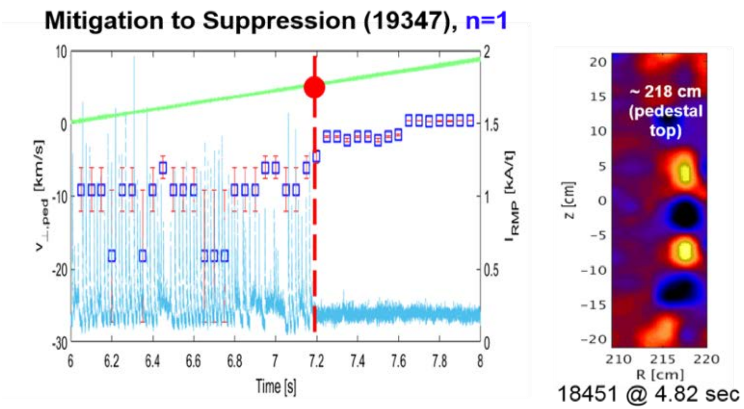

Figure 2. Transition from mitigation to suppression of edge-localized-mode (ELM) using RMP. The bifurcation of perpendicular electron rotation ($V_{\perp,e} \sim 0$) on pedestal top, nearly synchronous at the onset of ELM suppression (marked in vertical dash), has been directly measured on ECE imaging diagnostic, consistent with theory.

Overall, such robust RMP-driven ELM-suppression in KSTAR is expected to help us not only to address the critical physics issues on ELM-suppression but also to tame the fusion plasmas in a more favorable manner. Indeed, it is one of the main areas that the KSTAR team would be able to significantly contribute to in order to realize steady-state, high- performance fusion plasmas applicable to ITER and future reactors.

- 22. OI:10.1063/PT.6.2.20180216b

16 Feb 2018 in Politics & Policy

Laser program at University of Rochester targeted for shutdown

DOE budget proposes closing one of the three facilities that aid in the effort to attain fusion with lasers.

David Kramer

http://physicstoday.scitation.org/do/10.1063/PT.6.2.20180216b/full/?utm_source=Physics%20Today&utm_medium=email&utm_campaign=9181718_NQ%20-%20TWIP%2012–16%20February&dm_i=1Y69,5GSNQ,E1OV2B,L6HWL,1

The US Department of Energy intends to close a premier facility that has long led one of the three principal approaches to initiating nuclear fusion through the use of powerful lasers. DOE plans to initiate a "three-year rampdown" of the University of Rochester's Laboratory for Laser Energetics (LLE) in the fiscal year that begins in October, according to a summary of the agency's 2019 budget proposal released on 12 February.

The LLE, which houses the 40-kilojoule Omega laser, is one of three major facilities supported by the inertial confinement fusion (ICF) program of DOE's National Nuclear Security Administration. Complementing work at the much larger National Ignition Facility at Lawrence Livermore National Laboratory, the research at the LLE focuses on a direct-drive approach to ICF, in which peppercorn-sized capsules of deuterium and tritium are imploded by the 60-beam Omega. The second approach, at NIF, pursues indirect-drive fusion, in which light from the facility's 192 beams is converted to the x rays that implode capsules. A third approach, centered at Sandia National Laboratories' Z experimental device, explores implosion driven by electromagnetic fields.

Details of the ICF budget request had yet to be released at press time, but a summary of DOE's budget request says closure of the "aged" Omega, which has been operational since 1995, would be part of a rebalancing "to strengthen longer term support for [stockpile stewardship] as well as to respond to higher NNSA priorities." NNSA officials didn't immediately respond to requests for comment.

The LLE rampdown is part of a larger 20%, or $104 million, reduction proposed for the overall ICF program. The FY 2018 request for the LLE is $66.8 million, an increase from the $62.8 million appropriated in FY 2017. In the coming months Congress will decide whether to endorse the DOE recommendation.

Michael Campbell, LLE director, says he was "completely surprised" by the closure proposal. "I don't understand how such a decision could be made in the absence of any discussion with the program performers," he says, referring to the LLE and the other labs in the ICF program.

Campbell says he suspects that with the recent release of the Trump administration's Nuclear Posture Review, the NNSA decided to place greater emphasis on extending the lifetime of weapons and designing warheads at the expense of the underlying science program. "When these life extension programs are done in the 2030s, where are we going to get the talent that's going to produce the experts?" he says. "How do you test someone who's been doing computer codes? You test them by doing experiments in the real world. Omega, Z, and NIF do that."

Campbell says that two years ago, the directors of the NNSA's three weapons labs had backed continuing all three ICF programs, and that attaining laboratory fusion was "a critical element" of the science in support of the nuclear weapons stockpile. "What has changed in the past two years to make that statement different?"

Research at LLE and the other facilities has been funded principally to further nuclear weapons science. The ICF program's main objective has been to achieve ignition, the point at which fusion reactions release more energy than was required to create them. Neither Omega nor Z can produce enough energy to achieve ignition, and NIF has so far failed to achieve the milestone for which it was designed.

The ICF program and facilities also address other topics in high-energy-density physics, such as the behavior of materials under shock and extreme pressures. Richard Petrasso, head of the high-energy-density physics division at

MIT's plasma science and fusion center, says students from 40 universities have performed experiments and theoretical work at Omega in the past 20 years. MIT currently has six PhD students working on projects at the LLE. The DOE budget proposal is "a disaster," says Petrasso, who's done experiments for 25 years at Omega.

David Crandall, a former DOE official who now consults for the ICF program, says LLE is "the world-class facility for the development of new science and techniques in high energy density physics, and for the development of new diagnostic capabilities and people." He says the direct-drive approach, if it were upsized to NIF scale, could increase fusion yield compared to indirect drive. The challenge for both direct and indirect drive has been to achieve the necessary symmetry in the implosions.

Stephen Dean, president of Fusion Power Associates, says the NNSA may have seen an opening to target the LLE in the retirement last year of longtime LLE director Robert McCrory. Dean says McCrory was skilled at keeping DOE funding flowing, both through lobbying the New York congressional delegation and by actively supporting the NIF physics program.

Campbell says Congress has been very strong in its support for LLE, and he expects that in this case it "will react appropriately."