SMART APPLES FOR FUSION RESEARCH

“THIS IS THE WAY ITER EXPERIMENTS WILL HAVE TO BE RUN”

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During its new campaign the Joint European Torus (JET) says hello to more than 350 European fusion scientists. The world-wide largest magnetic fusion device currently prepares for a future deuterium-tritium campaign. Lorne Horton, JET Exploitation Manager, explains why coordinated European fusion research can be a role model for future ITER operations.

What are the major aims of the current experiments? Firstly, we will test and expand the limits of JET performance to prepare the planned deuterium-tritium operation. In addition, we will study the scaling of disruption mitigation to more ITER-like conditions. This means we will raise the temperature and the density to create conditions that come closer to those in ITER’s vessel. Thirdly, we will extend the range of detached divertor experiments to maximum input power and quantify the trade-off between divertor heat load mitigation and core plasma performance.

What fuel will you use for the current experiments? The experiments will initially be in deuterium. We expect to complement these experiments using hydrogen as the working gas, as the first step towards the planned JET isotope experiment, in which we compare hydrogen, deuterium and tritium. This also prepares for ITER’s non-active phase of operation.

What will be most challenging now? Most challenging will be combining high plasma performance, which will require maximum input power, with the power and energy limits of the ITER-like wall. Reaching this requires the high reliability of all of our important systems. This will be a major accomplishment and is viewed by the EUROfusion General Assembly, the highest decisive body in the EUROfusion consortium, as a necessary prerequisite to subsequently allow us to move on to experiments with tritium.

Have there been any changes made to the device since the last experimental campaign? We are presently re-commissioning the ITER-like antenna, which is expected to help with tungsten control by changing the impurity transport in the plasma core. We have also relocated our High Frequency Pellet Injector to a position from which we expect more efficient Edge Localised Mode (ELM) pacing and thus also tungsten control. Moreover, JET has received a third Disruption Mitigation Valve, which will guarantee appropriate disruption mitigation at high current. Additionally, we will study the geometrical requirements for disruption mitigation by comparing and combining all three of our systems.

How many researchers are participating in total? Are they all physicists? The researchers are primarily physicists. Without counting the hydrogen campaign, for which the Call for Participation has not yet been issued, we have almost 400 researchers participating from 24 different EUROfusion beneficiaries.

How did the establishment of EUROfusion support the current experimental campaigns at JET? We’ve been working towards the EUROfusion system since the beginning of 2014. We benefited from the former EFDA funding to cover visits to JET for experiments in 2014, but the analysis at home was covered by a EUROfusion task. The combination of experiment preparation, execution, analysis and publication into one call this time around will,
we hope, encourage a more holistic view to our work, with better preparation and more coordinated, in-depth analysis. This is the way ITER experiments will have to be run.

EUROfusion has also enabled us to better coordinate experiments between JET and the medium-sized tokamaks, ASDEX Upgrade and TCV. This means experimental proposals and schedules are discussed at a common planning meeting so that the best machine or machines are chosen in order to answer the related physics questions.

In my eyes, it is a very good sign to have approximately the same number of researchers planning to come to JET now as in former campaigns, whilst EUROfusion and many of the same people are participating in experiments at ASDEX Upgrade, TCV and soon Wendelstein 7-X.

Chinese delegates recently visited EUROfusion’s flagship, the Joint European Torus (JET), and test bed facilities at the Culham Centre for Fusion Energy. With their European colleagues the members of the Institute of Plasma Physics from the Chinese Academy of Science (ASIPP) and the Chinese Center for Fusion Science from the Southwestern Institute of Physics (SWIP) discussed the possible upgrade of JET’s additional heating system and Electron Cyclotron Resonance Heating. The talks were held in the context of JET’s extension beyond 2020 as being explored by EUROfusion. In addition, the Chinese delegation checked out training possibilities for their engineers and scientists at JET or the different medium sized tokamaks which EUROfusion owns. The Asian scientists showed particular interest in remote handling and the deuterium-tritium performance. Talks about an updated bilateral work programme between Chinese and European fusion researchers have been ongoing since last year. After nominating European and Chinese coordinators in April 2015 the following step is to jointly define working tasks. The next meeting will be held in January at EUROfusion’s other headquarter in Garching.

Full House

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A Chinese delegation paid a visit to the European Joint Torus (JET). The scientists are interested in remote handling and the deuterium-tritium performance. Picture: Rebecca Muir/EUROfusion
SHARE YOUR AMBITION AND CREATE SOMETHING BIG

A mbitious Grigori Matein just returned from his visit to the Joint European Torus (JET) in Culham. He has already been doing experiments in a lab during his spare time, and now the twenty-year-old has started studying physics at the Cambridge University. With excitement the winner of last year’s EUCYS prize tells us about his experiences at the biggest fusion experiment in operation in the world.

“I think science connects people. I will never forget how I sat down in the JET canteen for lunch talking to people from eight different countries. And I realised, it is not about your language or your nationality, it is about your ambition and your knowledge”, says the amazed Grigori Matein. As the winner of last year’s European Union Contest for Young Scientists (EUCYS) he has been invited to visit the Joint European Torus (JET) in Culham in September 2015. Even now he is still impressed by the sheer size of the experiment. “What they are doing is finding the magnitude of influence of different phenomena within the tokamak, how to make an experiment better. That’s what I did in my project, but my project was thousand times smaller”, explains the new student of physics.

“If you ask the right questions, science gives answers”, is the motto that drives Matein forward. He has been longing to enter into scientific research even before studying at university. For his investigations into the sounds of heated liquids, he was awarded the EUCYS prize in Poland last year. He is able to tell the concentration based on the way the liquids sound. “Investigation into that particular method have not been well developed”, he informs. When he was in the 11th grade, he decided to find out more about it. In his spare time, he carried out experiments at the Faculty of Physics in Sofia University in Bulgaria with the help of his supervisor.

It was his eagerness that helped Bulgarian Grigori to make his way to Cambridge. “It was not easy to apply here. But the prizes I received throughout the years surely helped to open the door for me”, he explains happily. It is understood that he will work hard for his grades.

Still being in awe of the impact fusion research may have on daily life or other scientific areas, Matein is looking forward to proceeding with his studies. Once he is done, he really aims to be part of the international fusion community: “I would be able to work with the best scientists on the edge of scientific knowledge. I would be able to share my fascination and together we could achieve something really big.”

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**EUCYS prize**: The European Union Contest supports young scientists in different areas of science and technology. The competition offers students the opportunity to challenge the best of their coevals at European level. As one of the eight EIROforum members EUROfusion is part of EUCYS. Each EIROforum member awards a special prize. EUROfusion physics offers a one week stay at JET in Culham to one lucky contestant.
Although very different in design, the architecture of spherical tokamaks creates some of the conditions that will be experienced in ITER. Their form, comparable to that of a cored apple, generates highly pressurised plasma at a relatively low magnetic field. One such device is the Mega Amp Spherical Tokamak (MAST) in Culham which is currently undergoing major upgrades in order to become MAST Upgrade. Programme leader Andrew Kirk explains how these improvements will help pave the way for ITER and the first fusion power plant and why the European team is happy to have the National Spherical Torus Experiment in Princeton as sibling across the pond.
MAST Upgrade will help us look at some aspects of ITER operation more easily than on other devices,” states Andrew Kirk enthusiastically. The head of the MAST Upgrade programme can hardly wait for his upgraded tokamak to start operating. Unlike the usual doughnut shaped vessel, ‘his’ tokamak is a spherical one. It has a design which can be compared to a cored apple thus confining the plasma into a more compressed shape.

**UNDER PRESSURE**

The advantage of a compressed tokamak is its lower magnetic field which is able to confine highly pressurised plasma. These plasmas have some of the characteristics that will be produced in a burning plasma in ITER. “The special design of a spherical tokamak allows it to operate at a lower magnetic field which, since superconducting magnets are very expensive, may help to reduce the cost of future reactors.” In figures this means that Andrew Kirk and his colleagues will attempt to create a plasma pressure of 2-3 atmospheres contained using a magnetic field of 0.8 Tesla. This will result in a so-called ‘high beta plasma,’ whereby beta refers to the ratio of plasma pressure to magnetic pressure.

**MAST ON A MISSION**

The tokamak is currently undergoing a major upgrade to serve several missions laid out in the European fusion roadmap. The makeover of the 16-year-old tokamak at Culham Centre for Fusion Energy began in 2013. It includes a novel divertor, several new power supplies, an upgraded heating system and modern diagnostic tools. “In fact, with this upgrade we hope to solve three major issues in fusion research: Handling the power exhaust with the help of new divertor concepts, investigating turbulence in the plasma and exploring fast particles, which can cause energy loss,” says Kirk.

**ALL EYES ON THE SUPER-X-DIVERTOR**

Looking at novel divertor concepts will support Mission 2 of the European fusion roadmap: Handling the power that is exhausted during a fusion experiment. In a normal steady state fusion reaction, the charged plasma particles follow magnetic lines. In tokamaks, magnetic lines divert the particles into the bottom or the top of the vessel, called the divertor. MAST Upgrade needs to be able to handle a higher peak power density than traditional tokamaks due to the compressed shape of the device. Consequently, the researchers are looking for a way to reduce the high particle flux. The unique Super-X-Divertor at the upgrade in Culham attempts to implement this by increasing the distance the particles must travel along an “extended leg” and thus providing a larger divertor area. “Like a river that spreads out into a larger delta, the stream slows down,” describes Kirk. Moreover, the updated spherical tokamak provides a closed divertor area, a major change from MAST. This allows the investigators to introduce gases and radiate the energy carried by the particles.

**A DIVERTOR FOR DEMO**

MAST Upgrade will be the only device able to operate a closed pumped divertor with an extended leg. Thanks to a flexible divertor, it also provides the ability to compare different divertor layouts and examine which one will be most useful for DEMO, the first power plant. DEMO is intended to show how to generate electricity from fusion and introduce it into the grid. The first experimental campaign at the spherical tokamak will take place in autumn 2017 and is highly anticipated by Xavier Litaudon, Head of EUROfusion’s ITER Physics department: “MAST Upgrade will advance physics understanding to support the fusion energy development along the key missions of the European roadmap to the realisation of fusion energy, in particular by addressing the challenging exhaust physics and control issues for ITER and DEMO.”

**UNDERSTANDING TURBULENCES**

The second goal is to investigate and control turbulence, a process that increases the rate at which plasma and heat are lost from the plasma. Understanding turbulence is es-
“MAST U and NSTX U will identify the best approaches of using conventional and spherical tokamaks for fusion power production”

Jonathan Menard, NSTX Upgrade Programme Director

essential for optimising the performance of ITER and fusion power plants. The types of plasmas and diagnostics available in MAST Upgrade give it the unique capability to study these processes.

FASTER THAN THE SPEED OF SOUND

Just as an airplane travelling faster than the speed of sound leads to an instability known as a “sonic boom”, fast ions in a fusion plasma lead to instabilities that may increase losses of particles from the confined plasma thus reducing its efficiency. In ITER, these will be the alpha particles produced by the fusion reaction. In the spherical tokamak, the effect of such alphas can be simulated using particles which are injected to heat the plasma. The upgrades to the heating systems will allow the scientists to study the effects of the turbulence which is caused by these fast particles in detail.

A SIBLING ABROAD

The EUROfusion experiment is not the only modernised spherical fusion device that will help to explore some of the conditions encountered in ITER. On the other side of the ocean, the National Spherical Torus Experiment (NSTX) also shines in new splendour. The tokamak at the Princeton Plasma Physics Laboratory (PPPL) in the US saw its first plasma in August after undergoing a multi-million dollar upgrade. The parallel upgrades are not accidental.

BUILDING COMPLEMENTARY DEVICES

On the contrary, they have been carefully planned. Scientific discussions between CCFE and PPPL have been ongoing for several years. The knowledge exchange among fusion scientists from both sides of the Atlantic Ocean is dearly desired. “We prepared our upgrades more or less together. Members from both labs sit on both of the advisory boards. As a matter of fact, we decided to build the devices complementary to each other,” explains Andrew Kirk. While NSTX Upgrade (NSTX U) concentrates on looking at the core of the plasma, MAST Upgrade focuses more on examining the edge.

THE CORE OF THE APPLE

According to Jonathan Menard, the Programme Director for the NSTX Upgrade, it will be the first spherical tokamak to try and sustain high plasma current and pressure using a combination of externally injected current and self-generated plasma current. Sustainment at high plasma current and pressure is essential for any future tokamak in order to enable it to operate continuously at high fusion power. The research team on NSTX U will inform MAST U on the subject of how to optimise its sustainment, since the two devices use somewhat different approaches.

In plasma edge research, the American tokamak is the only device capable of exploring a very advanced approach to expanding the power exhaust channel for reducing heat loads that might otherwise damage the reactor walls. Such heat load reduction is most probably essential to making smaller tokamak power plants viable.

SOLVING KEY CHALLENGES TOGETHER

The MAST U approach complements that of NSTX U, which will explore liquid metals as a means of handling high edge power exhaust. “Together, MAST U and NSTX U will help identify the best approaches to solving the key challenges of using conventional and spherical tokamaks for sustained fusion power production”, states Menard.
SPILADY TAKES ATOMIC SIMULATIONS TO A NEW LEVEL

“Spilady is a benchmark for material simulations”, says Sergei Dudarev, Head of the Materials Modelling Group at the Culham Centre for Fusion Energy (CCFE). With the help of EUROfusion’s Enabling Researcher Grant Chinese and European researchers created the Spin-Lattice Dynamics Simulation Programme. The unique software allows to model the behaviour of heated iron materials down to an atomic level. In fact, the fusion invention already raised interest in the information technology.

“Converting a scientific idea into something useful requires time, and the availability of time at the appropriate moment is often quite limited”, says Dudarev. It was ten years ago when Dudarev, and his colleague Peter Derlet from the Swiss Paul Scherrer Institute, first figured out that the traditional method of simulating materials, called molecular dynamics, is insufficient when it comes to modelling the behaviour of magnetic materials under a harsh environment.

SPILADY MAKES A DIFFERENCE

The programme now provides the basis for further steps of material simulation and testing, even beyond fusion research. Whenever magnetic aspects of material behaviour play a role, this programme might make a difference. “It can be used, for example, to investigate materials used for information storage, such as hard disks in computers”, adds Dudarev. In fact, a well-known company which specialises in information technology has already knocked at Dudarev’s door. With their interest in modelling magnetic storage relevant alloys, the enterprise asked for a copy of SPILADY.

VARIETY OF MATERIAL CONDITIONS

Before SPILADY, it was impossible to analyse the effect of magnetism on atomistic dynamic processes and on the thermodynamic properties of magnetic alloys. In fusion tokamaks, a strong magnetic field is used for the confinement of plasma. The steel components of a fusion reactor are exposed to such strong magnetic fields thus are expected to work at high temperatures. This affects the thermodynamic state of the steel and its response to mechanical loads.

SEEKING FEEDBACK FROM NON-FUSION APPLICATIONS

The British-Chinese team shares its software for free on a website. The colleagues are now hoping to encourage usage of the code and trigger feedback, especially from non-fusion applications. “This should help us to improve our models for steel at high temperatures”, hopes Dudarev.

JOINING FORCES IN CULHAM AND HONG KONG

The lack of a proper simulation programme also bothered Chung Ho Woo, a Chair Professor at the City University of Hong Kong and his associate Pui-Wai (Leo) Ma, who at that time was pursuing his PhD project. Ma, Woo and Dudarev accordingly joined forces and developed a code which has advanced atomistic simulations to a new level. They incorporated the effect of magnetism into the framework of molecular dynamics simulations.

“But like any homemade code, it was not very user-friendly”, admits Dudarev. The grant from EUROfusion in 2014 finally enabled the main code developer Ma to write a new code, based on the developments that had occurred since 2007, and thus create a new simulation tool.

Spilady can be downloaded here: http://spilady.ccfe.ac.uk

The graph shows the model of steel atom under the influence of heat.
Relocation is not much fun, at least for most of the people involved. But Thomas Morgan can hardly wait for his institute to finish moving from the small town of Nieuwegein to the Science Park of the Eindhoven University of Technology. Moving literally beams up the Dutch Institute for Fundamental Energy Research (DIFFER) thanks to several upgrades on its devices Magnum-PSI and Pilot-PSI.
“The delivery of the ion beam and the new magnet is very exciting for us and will offer many opportunities,” says Thomas Morgan, project leader for Advanced Divertor Concepts at DIFFER. The research of the Dutch institute covers Plasma Surface Interactions (PSI) which are part of the European Fusion Roadmap. Now, these devices set new standards with upgrades to their linear plasma generator, Magnum-PSI, and its older sister experiment, Pilot-PSI.

**FLUXES OF ITER**

The PSI devices at DIFFER aim to create ITER-like scenarios in order to test materials. In ITER, the constituents of the vessel must withstand extremely harsh conditions. “In existing fusion experiments we are unable to attain the conditions expected in ITER. Usually, we operate tokamaks with heat and particle fluxes which are much lower than that, and for timescales that are much smaller. To know how the plasma will affect the surface, we need a device which is able to replicate those high-flux and extended conditions”, explains Morgan. “Right now at DIFFER we can attain the conditions, but not the times.”

In order to operate under such settings, Magnum-PSI’s old copper magnets will be replaced with a superconducting one. This new system offers a stronger magnetic field and does not pose electrical resistance, meaning it keeps the plasma beam switched on for hours on end. Therefore the superconducting magnet will allow Magnum-PSI to explore long-term plasma effects for the first time. For example, the PSI facilities can operate in a pulsed mode on top of the steady state plasma, so that the experiments can mimic the energy outbursts of Edge Localised Modes (ELMs) that wall materials also face in real tokamaks. “Now we can easily create thousands, even millions of these ELM-like events in a reasonable time.”

**MATERIAL TESTING IN THE VACUUM**

While many diagnostics monitor the plasma and surface evolution during exposure, identifying what is happening in the near-surface region, down to a few micrometres below the surface, is much more difficult. This is where the Ion Beam Facility comes into play, Morgan’s favourite part of the relocation. The new building offers space for this sort of additional large equipment that can be used with Magnum-PSI. DIFFER now owns a 3.5 MV singletron accelerator which was acquired second hand from the local company Accelerator Technologies BV in 2014. The singletron creates a thin stream of high-energy (MeV) ions which can non-destructively give information about what a material contains at different depths. This will be used to make in-situ ion-beam analysis (IBA) measurements in Magnum-PSI after plasma exposure.

**STOP AND MEASURE**

Normally, scientists carry out the IBA process at a separate facility after they have completed their experiments. Magnum-PSI will improve on this by allowing measurements to be taken directly afterwards, or enabling the scientists to pause halfway through, measure, and then continue. In Pilot-PSI, it is planned to go one step further and carry out ion beam analysis at the same time as intense plasma exposure. “This novel combination allows us to monitor how the sample is changing as we are exposing it to these high flux plasmas”, describes Morgan. “This should open a lot of exciting new possibilities for experiments.”

**EUROFUSION EXPERIMENTS NEXT SUMMER**

Now, the European research on plasma surface interaction can pick up pace. “In November, the tasks for the EUROfusion experimental campaign will be defined”, Morgan explains the next steps. This coming summer, Magnum-PSI will be restarted. By then the enhancements will have been installed and the experiments will have commenced. Researchers from the EUROfusion programme will be able to begin exploring how tungsten monoblocks behave on the long term.
On 22nd September, the Center for Research in Plasma Physics (CRPP) became the Swiss Plasma Center (SPC) – a new name for Europe’s fusion research to count on. Since 1992, the Lausanne-based lab has hosted the ‘Tokamak à Configuration Variable’ (TCV), now one of three EUROfusion Medium Sized Tokamaks (MST). It has undergone a major upgrade and will not rest on its laurels. Currently, more than 120 European scientists are expected to attend experimental campaigns at the Swiss tokamak. A fact, which encourages Ambrogio Fasoli, the Director of the SPC. In his opinion, the ability to welcome so many European fusion scientists shows how exchange without borders is an advantage for all sides.
What does the new name of your institute mean for European fusion research?
It means that European fusion can count on an even stronger partner in Switzerland, with strong political support and solid bases across the whole country, with a long-term commitment to fusion research. We will continue to provide education and training for ITER and DEMO generations at all levels.

TCV will experience further upgrades within the next years. How do you proceed?
We are implementing two sets of upgrades. First we are investing about nine million Swiss francs to provide TCV with an improved heating system in order to approach reactor relevant conditions. Second, as part of the ‘rebranding’ of CRPP into the Swiss Plasma Center, we will invest another ten million Swiss francs over the next four years. This investment will enable our lab to expand on two thrust areas: the TCV tokamak systems and smaller and simpler devices for studies of basic processes of interest for fusion but also for astrophysics and other plasma industrial and societal applications.

Which ones?
These include, for example, the problem of plasma rotation which is important for tokamak stability, and that of cross-scale turbulences in complex systems which is crucial for energy transport in fusion reactors. These phenomena happen in many plasma systems, for example, in solar wind and proto-stellar plasmas. This means that synergies with space and astrophysics are possible. Moreover, we are able to explore environmental applications of plasmas, such as water purification, plasma sterilisation, or plasma medicine.

What is the central aim of the upgrades?
We will build a new modular structure at the plasma edge to create an exhaust chamber of variable closure using different length baffles. With this we will systematically investigate and possibly optimise the magnetic configurations for the plasma edge, addressing the crucial problem of heat and particle exhausts. We are also exploring the potential use of high temperature superconductors for the necessary additional divertor coils in order to demonstrate a potential key technology for future tokamaks. Furthermore, a second 1 MW neutral beam heating system with high-energy capabilities will be installed, enabling us to study fundamental physics issues for burning plasma regimes, namely plasma rotation and fast ions.

How will the recent upgrades serve the European fusion roadmap?
TCV is characterised by the most extreme plasma shaping capability worldwide, the highest microwave power concentration in the plasma, and the largest degree of flexibility in its heating and control schemes. EUROfusion will use these advantages on behalf of ITER, focussing on exhaust, heating and control techniques in increasingly reactor relevant conditions. This will contribute to three Missions of the European fusion roadmap: Plasma Operation, Heat Exhaust and DEMO.

What does it mean you welcoming so many European fusion scientists at the Swiss Plasma Center?
I am looking forward to hosting many first class European researchers who will bring ideas, enthusiasm, knowledge and expertise to our Center. And who will, in turn, discover a state-of-the-art national lab at École Polytechnique Fédérale de Lausanne, one of the most dynamic universities in the heart of Europe.

For me, it really means that the Swiss Plasma Center is fully integrated in the European fusion programme, and shares the long term vision of the European fusion roadmap. The Swiss people voted against the European freedom of movement. In this delicate moment, the renaming of our Center underlines how essential integration is, for both sides. Switzerland has become an important partner in science for Europe and the world, thanks to it being open for international exchanges. By working with the EU programme, we should – and I’m sure we will – find a way to circumvent the political difficulties and to continue such progression. There is no way back.

Fusion, the MST campaigns and the presence of so many colleagues from the other fusion labs provide a very concrete example of the fact that coordinated exchanges at this level constitute the most effective way to foster excellence and focus in research.
INTERNATIONAL PLASMA CONFERENCE

The biennial conference, which was held in Warsaw from 7th to 11th September, brought together around one hundred scientists from all over the world to take stock of possible applications of the fourth state of matter. This year’s event covered a wide range of topics from magnetic and laser plasma, through to material studies of plasma in the universe. Both the progress in magnetic confinement plasma and laser-induced fusion were emphasised. Presentations and posters ranged from plasma physics, diagnostics and applications.

STEADY-STATE OPERATIONS AND LASER INDUCED IMPLOSION

Xavier Litaudon, Head of the ITER Physics Department in EUROfusion, described the European efforts addressing long pulses and steady-state issues of magnetically confined plasmas. Andreas Dinklage, from the Max Planck Institute for Plasma Physics (IPP), provided information about the current status and the preparation of the first experimental campaigns at Wendelstein-7X stellarator in Greifswald (Germany). Jose Milovich also presented new developments from his lab towards improving laser-induced implosion of deuterium-tritium targets at the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (US).
Among others, the participants discussed the different applications of plasma. Taiwanese researcher Wei Yu Chen from the University of Sheffield (UK) has investigated the most unusual of plasma phenomena. From a biologist’s point of view he gave a lecture on a special usage of Cold Plasma Processes Pretreatment.

Furthermore, speakers addressed advanced soft X-ray diagnostics using of Gas Electron Multiplier (GEM) detectors, new measuring methods and devices for ion, neutron and gamma diagnostics, tracer techniques as well as the development of laser induced breakdown spectroscopy.

CONFERENCE FOSTERED TALKS

Above all, the conference strengthened personal contacts and fostered the exchange of information which provokes new scientific ideas. “The event encouraged a good degree of interaction between the participants, and pretty much every talk resulted in at least two or three questions from the audience”, noted John Pasley from the York University (UK).

Last but not least, the speakers also had the option of publishing conference articles in the international journals Physica Scripta and Nukleonika.

FEMALE PARTICIPATION INCREASED

PLASMA 2015 gathered participants from 20 countries. The conference statistics revealed that the participation of women has increased by 30 percent compared to the previous years. Moreover, according to the organisers, research in plasma physics is becoming a more attractive proposition for young scientists. It looks as if the development of such crucial projects like ITER in France, Wendelstein 7-X in Germany or NIF in the US will be able to maintain this tendency for future decades. This development will hopefully have been proved right by the time the next PLASMA conference comes around. The next event should take place in 2017 in Poland.

Find out more details about PLASMA 2015 here: plasma2015.ipplm.pl

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Installation of the divertor casing inside the WEST vacuum vessel using an upper port plug.

It is a complete change to the device”, says Jérôme Bucalossi. The project leader of WEST, the only tokamak in EUROfusion’s programme to specifically test plasma facing components (PFC), is excited: a lot of work has been done to ensure that the Tungsten (or Wolfram in German) Environment in Steady-state Tokamak matches the requirements of the European fusion research.

After a complete make-over of WEST, the former Tore Supra tokamak, which is housed at the French research centre CEA in Cadarache, is expected to produce its first plasma at the end of 2016. “The trickiest thing was to install the infrared thermography systems. These observe the temperature of the plasma facing components during fusion experiments. The challenge was to integrate the system properly into the existing vessel”, explains Bucalossi.

Detect overheating

“There is a lot to cover and the footage must be in very high resolution, so that we can detect whether the components are overheating or if there are any other problems”, he adds. To inspect the vessel sufficiently, WEST uses a so called “Articulated Inspection Arm”. Like a snake with a camera as its head it enters through a 20 cm flange and winds along points in the vessel which are usually difficult to access. This allows us to precisely monitor the vessel wall between fusion experiments without breaking the vacuum.

60 diagnostics to be characterised

WEST has integrated a total of 60 diagnostics including visible spectroscopy designed to monitor tungsten erosion. It was also challenging to ensure the accurate integration of new diagnostics in the reduced available volume while minimising the modification of existing diagnostics. Now, each of the diagnostics systems can be removed without affecting the others.

With its special capability to test actively cooled PFCs in long lasting plasma, WEST complements the existing EUROfusion facilities by combining ITER divertor high heat flux technology and tokamak operation.

The campaign for EUROfusion which is planned for late November 2016, will investigate power load and the power deposition profile from the new divertor. A call for participation in the WEST campaign is currently being prepared and will be communicated before the end of this year. The experiments will mainly serve Mission 2 of the European fusion roadmap: Heat-exhaust systems.
Recent graduate from Drexel University (USA), Matthew Parsons wants to pursue his lifetime goal: working for ITER. He aims to develop an algorithm capable of predicting disruptions, sudden and unavoidable losses of particles. An algorithm that will be invaluable for the world’s biggest fusion experiment. The 22-year-old with a Bachelor of Science in physics is currently applying for a Fulbright Grant that will enable him to work with the staff at ITER for a year.

You said in an article, that you want to change the world when it comes to solving the demanding energy issues. Why do you think fusion will be the solution?
I think one of the main selling points of fusion is that there is an abundant amount of fuel. A fusion reactor also operates independent of weather, daylight or night. It will always be available and it will not produce long-lived radioactivity like fission does.

When did you first hear about fusion?
When I was a Boy Scout at the age of about eleven I got my first merit badge, not for making tents or camping, but for learning about nuclear science, fusion and fission. I liked the energy aspects of it and of course getting a glimpse of the finer mechanics behind our universe. I later decided to study physics and find out what opportunities are available in this area.

You are using JET’s data for your studies on disruptions. How did you first learn about JET?
In my first year of college, in 2011, I chose current fusion research as a topic for my writing course and that is when I first heard about JET ... and ITER of course.

Why are you developing models for a EUROfusion experiment in the US?
For several years JET has had an ongoing project, called the “Advanced Predictor of Disruptions” and they were seeking help with developing it further. Right at the end of my coop, a practical training programme I did at PPPL, I learned about that project. That is why I did a second coop, also at PPPL, to help develop a tool that predicts disruptions. In physics research, the traditional way to go about solving problems is hypothesis driven. You come up with a number of ideas on the theory side and prove it. With disruptions, there are so many things going on at the same time, it is really complicated and much more extensive than we are able to describe. One interesting idea is to predict disruptions using statistical methods. We have a lot of data from JET.

Why do you want to support ITER?
During my first year writing project, I remember looking at websites for all of the experiments. Everyone was doing research in support of ITER and I got an inkling of the significance of the project. I definitely wanted to be part of the team. I am very optimistic about the changes which the Director-General Bigot just announced. One of the main concerns of the US Congress, which approves money for ITER, is spending the money abroad when it could be used here instead. I think what they are paying for ITER is almost insignificant when you look at the entire project and its future outcome: a very small investment for a very great reward.

Matthew Parsons submitted his application for a Fulbright grant at the beginning of October. He attached a very decisive letter of support from David Campbell, the Head of ITER’s Science and Operations Department, stating among other things: “We believe that the experience which he [Parsons] has gained in his area of particular interest, the development of data-driven and physics-based techniques for the prediction/detection of disruptions, will provide an excellent basis for the research project which he would pursue at ITER. [...]”
In September, representatives from Euratom, the European Commission and EUROfusion paid a visit to Ukraine to start negotiations for an associate partnership. The delegation visited Kyiv where a fusion-fission information day was organised as well as the Kharkov Institute of Physics and Technology (KIPT) and the V.N. Karazin Kharkiv National University. Unnoticed, Ukrainian researchers have been contributing towards European fusion research for years.
"The visit from members of EUROfusion and the European Commission along with the prospect of Ukraine joining the Euratom programme will open up many more opportunities", says Ludmila Krupnik. The fusion scientist, who has been working at KIPT for more than 60 years, was extremely delighted to guide the representatives on a tour of the laboratory in Kharkov. Alejandro Zurita, Head of Sector of International Agreements (European Commission), along with Frederick Mariën, the coordinator for Euratom research and innovation Horizontal Activities and Tony Donné, EUROfusion Programme Manager, travelled to the National Academy of Sciences of Ukraine to exchange information about the European fusion and fusion programme and to find out about the current research in the country.

"The history of this particular method started at the end of the 1960s, just here at KIPT. Our group has finally supplied equipment to several fusion devices in Russia, Spain and Germany with active participation in experimental programmes."

Ludmila Krupnik

KEY AREAS WERE DEFINED IN 2013

Under the umbrella of the National Academy of Sciences of Ukraine, several laboratories, such as KIPT, the Institute for Nuclear Research, the Institute for Applied Physics and the Bogolyubov Institute for Theoretical Physics have been discussing potential associations with Euratom for more than a decade. In 2013, the coordination committee defined key areas with regard to the European fusion roadmap: “We hope to contribute to the plasma regimes of steady state operations. Our objectives also include heat exhaust and the optimisation of stellarators”, explains Anatoly Zagorodny, Vice-president of the National Academy of Sciences.

"Becoming an associate partner in the EUROfusion programme would strengthen fusion research in our institute and in Ukraine, in general."

Yaroslav Kolesnichenko

SERVING EUROPEAN RESEARCH FOR DECADES

“EUROfusion has already benefited from Ukrainian investigations – but only on a bilateral level with individual researchers and their teams”, says Tony Donné. These researchers include Ludmila Krupnik who focuses on diagnostics. In 1990, her work on heavy ion beams contributed to the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) in Madrid.

HIGHLY EXPERIENCED RESEARCHERS

Even brand new devices in the EUROfusion programme have taken advantage of Ukrainian fusion research. Yaroslav Kolesnichenko, Head of the Fusion Theory Division at the Kiev Institute for Nuclear Research Prospect, has been involved in fusion for more than 35 years. He and his group currently collaborate on the physics of energetic ions at the stellarator Wendelstein 7-X.

EQUAL PARTNER IN EUROPEAN FUSION SCIENCE

EUROfusion’s Tony Donné adds that if the negotiations are successful, then the Ukrainian impact on European fusion research should also increase. “This creates opportunities for young fusion scientists to study abroad and then return to their home labs.” He was informed that today it is the Ukrainian industry that attracts young scientists after they complete their studies.

"Ukraine provides a great potential in the field of plasma physics. I think that the partnership with EUROfusion will help to fully reveal and realise this potential. This cooperation will be useful for both partners."

Olena Turianska

One of the fusion experts of the future is Olena Turianska. She is a graduate student from the School of Physics and Technology at the V. N. Karazin Kharkiv National University and specialises in plasma physics. She has already taken advantage of the good relationships with Europe and attended this year’s Summer School held at the Max Planck Institute for Plasma Physics in Garching: “Ukraine provides a great potential in the field of plasma physics. I think that the partnership with EUROfusion will help to fully reveal and realise this potential. This cooperation will be useful for both partners”, says Turianska. After all, a closer collaboration between Ukrainian and European fusion research is also expected by academy representative Anatoly Zagorodny:

"For me this partnership signifies that our European colleagues recognise our high standards. And this will establish the status of Ukraine as an equal partner on the scientific map of Europe."

Anatoly Zagorodny
For his work on divertor flow simulations at JT-60 SA Cristian Gleason-González received the Fusion Engineering and Design Student Award. The International Standing Committee (ISC) for the International Symposium on Fusion Nuclear Technology (ISFNT) has honoured the student from the Karlsruhe Institute for Technology for his outstanding contributions to the field of Fusion Nuclear Technology. The award was conveyed during the ISFNT held in September 2015 in Jeju Island, South Korea. Gleason-González, who is also involved in the research of EUROfusion’s devices ASDEX Upgrade and JET, is stunned: “In a way this award reflects the great importance the particle exhaust system has in present and future fusion devices. The prize acknowledges the remarkable efforts done in this matter by means of a joint collaboration between Europe and Japan.” Gleason-González’ passion is to understand the physical mechanisms underlying complex processes necessary to apply this knowledge for a future fusion power generation. “I would like to continue contributing to progress for both tokamak and stellators in the experimental campaigns of European and non-European devices. I look forward to continuously exchanging and collaborating with other research units worldwide.”
The 15th International Workshop on Plasma Edge Theory recently took place in Nara, Japan. Discussing, among other things, Basic Edge Plasma Theory, and European research had a big impact on the event. Atsushi Fukujama, organiser of the International Fusion Workshop, estimated that about 35 percent of all presented outcomes were derived from European fusion research. Eight of the 14 talks were held by a European fusion scientist. For example, Bruce Scott from the German Max-Planck-Institute for Plasma Physics who presented ‘Gyrokinetic theory and dynamics of the tokamak edge’. Patrick Tamain from the French institute CEA Cadarache was also part of the international community of fusion scientists, which gathered at the Kasugano International Forum in the Japanese town of Nara. Tamain highlighted the interplay between plasma turbulence and particle injection in 3D global turbulence simulations.
“Now, tokamaks’ rebellious cousin is stepping out of the shadows. [...] It looks a bit like Han Solo’s Millennium Falcon, towed in for repairs after a run-in with the Imperial fleet.”

Science journalist Daniel Clery about the launch of Wendelstein 7-X, October 21st, 2015
http://www.tinyurl.com/psjffw3

“People are already talking about it. It depends how good the results are. If the results are positive, there’ll be a lot of excitement.”

David Gates, Head of stellarator physics at Princeton Plasma Physics Laboratory in the same article

“[…] the hopes of Europe’s future being a nuclear fusion-powered one may well rest on the ability of this machine to perform as expected. Watch this space.”

Author Colin Jeffrey on gizmag.com about the same topic, October 25th, 2015

“[…] when we talk about energy, we need research that keeps all options open. And one of these options is nuclear fusion.”

Johanna Wanka, German Federal Minister for Education and Research on Dailymail.com, October 26th, 2015

“In all of our selections, it’s not about a start-up versus something else. It’s about the quality of the idea.”

Eric A. Rohlfing, Deputy Director for technology of the Advanced Research Projects Agency-Energy, the US government agency that made the grants for fusion research, October 26th, 2015
http://www.tinyurl.com/px4ch3s

“Soon enough, we hope to move from fission to fusion technology just as Back to the Future II predicted. This would help Doc Brown avoid troubles with the terrorists in the original movie – we use water as fusion fuel and you cannot make an atomic bomb with water!”

Egemen Kolemen, assistant professor at the Princeton Plasma Physics Laboratory in an interview with forbes.com for the Back-to-the-Future-day on October 21st, 2015
http://www.tinyurl.com/pfyvty3

“Even if stellarators work well, the 30-year rule, or something pretty close to it, is likely to apply. And, by the middle of the century, the world’s energy landscape will probably look completely different from now.”

The Economist, October 24th, 2015
EUROPEAN CONSORTIUM FOR THE DEVELOPMENT OF FUSION ENERGY
REALISING FUSION ELECTRICITY BY 2050

Our partners:
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