YES, IT WORKS!
ITER-LIKE-WALL DELIVERS ENCOURAGING RESULTS

NEW HEAD OF EFDA ITER PHYSICS DEPARTMENT

SELF SUFFICIENT FUSION REACTOR

PLASMA FINGERS POINT TO THE TAMING OF THE ELM
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RUDOLF NEU TO HEAD UP EFDA ITER PHYSICS DEPARTMENT

Rudi Neu will take up his new position in the third quarter of 2012, after the JET experimental campaign ends. Rudi Neu is the fusion community’s “Tungsten-Man”. He comes from IPP Germany, where he managed the implementation of an all-tungsten wall in ASDEX Upgrade. Visitors to his office can do weightlifting with harmlessly small-looking but very heavy tungsten bricks. Rudi Neu was Leader of the EFDA Task Force on Plasma Wall Interaction and currently leads the JET Task Force E1, which oversees the first operation of JET with the ITER-Like-Wall. He is also Professor for Experimental Physics at Tübingen University, Germany.

Welcome to EFDA, Rudi! What is the first thing you will do in your new job?

Hire new people! The ITER Physics Department is short-staffed due to expiring contracts, so we are filling two open positions.

EFDA also appointed a Deputy Leader to the ITER Physics Department – Darren McDonald. How do Darren and you distribute the responsibilities?

Darren has a modelling background, while I am an experimentalist, so we complement each other well. He will take care of Integrated Tokamak Modelling, of EFDA’s involvement in the collaborative use of super computers and of the transport and magnetohydrodynamic activities. Darren will report to me but I do not plan to get involved in the details.
What fields of research will the newly appointed officers cover?

We need to cover the areas of Diagnostic, Heating and Current Drive and Plasma Wall Interaction.

The next European Research Framework Programme starts in 2014. What are your aims for the remaining 1.5 years?

We will carry on with the current ITER Physics Programme. As you know, the Programme underwent a major redesign. It is now aligned along key physics issues rather than individual disciplines, which are covered by the respective task forces. Many procedures still need to be further optimised in discussion with the Task Force and Topical Group Leaders. Let’s take the ELM instabilities, for example. An ELM project involves several disciplines. How do we design meaningful interfaces? What kind of meetings will we need? How do we break the overall task down into individual calls?

At the same time we face serious financial constraints. The EFDA ITER Physics Programme has a very limited budget, especially considering the fact that we support 28 Associates. Of course, EFDA only finances one fifth of a task and the Associate contributes the remaining 80 percent, so the total leverage is much higher. But the Associate, bearing most of the investment, will consider carefully whether a task fits into its line of work. The question therefore is, how we can convince the Associates that fusion research has a much bigger impact if we agree on common key research issues.

What will be the main research issues until 2014?

The EFDA ITER Physics Programme focuses on eleven research areas, which are oriented along the key issues for ITER. Most projects will run through 2013, but some might finish earlier. That is our chance to bring in new issues, for instance real time diagnostics for plasma control.

Furthermore, EFDA, and also the Commission feel that we need to work on physics for the planned demonstration reactor DEMO. Experiments in ITER will not answer all remaining questions. So we have to develop other methods of investigation and see how we can best utilize the existing machines.

You have known European fusion research from the perspective of the Associate, as EFDA Task Force Leader and as a JET scientist. If you look beyond 2013 – where do you see the largest value of an umbrella organisation like EFDA?

The highest value is the platform for collaborations. I worked in university research and using a device at another institution was organised via personal contacts. To collaborate across Europe we need a better framework that facilitates the exchange of scientists and the common use of devices. This aspect will become more important as we will have to concentrate our research on fewer devices due to the financial constraints. The common use of machines will become heavier, which EFDA will have to manage. We can benefit from the experience we've accumulated at JET. EFDA is already an organisation in which all laboratories meet and agree on strategies. EFDA’s financial resources must be enhanced, too. Mobility support to exchange scientists or finance their stay at an experiment, for instance, will become more important.

The other issue is shaping the research programme. If EFDA wants to go in that direction and ensure that important research tasks are addressed, we need more funding.
Plasma research: Star-makers and star-gazers team up

The Max Planck Princeton Research Centre for Plasma Physics – a cooperation between Max Planck Society and Princeton University – starts operating in autumn this year.

“When it comes to plasmas, fusion researchers and astrophysicists can benefit greatly from each other,” says Sibylle Günter, Director of IPP and initiator of the new Max Planck Princeton Centre. “In fusion, we manipulate and measure plasmas, while astrophysicists observe them.” Fusion has, for instance, developed plasma models and computer codes, which complement the fluid or particle-based models used in astrophysics. The centre will enable researchers to make best use of such synergies by providing the framework to establish close cooperations, continues Günter: “In its beginning, fusion research had close ties to astrophysics, but this has to be reinforced these days.”

Partners of the Max Planck Princeton Centre are the Max Planck Institute for Plasma Physics (IPP) and the Princeton Plasma Physics Laboratory (PPPL), one of the leading U.S. institutes in this field. IPP and PPPL already collaborate on IPP’s stellarator Wendelstein 7-X, which is under construction. On the part of astrophysics, the new centre includes the Max Planck Institutes for Solar System Research and for Astrophysics, as well as Princeton University’s Department for Astrophysical Sciences. The centre is funded by the Max Planck Society, Princeton University, National Science Foundation and the U.S. Department of Energy. On the German side, funding is guaranteed for five years, which can be extended for another five years after successful evaluation.

Four research topics. Sibylle Günter, PPPL Director Stewart Prager and Jim Stone from Princeton University’s Department for Astrophysical Sciences form the Leading Team of the centre. They set the main research direction and see that the centre comes to live – by organising common workshops, for instance. The research will focus on four main topics: Reconnection – changes in the magnetic field structure of a plasma – is a phenomenon that occurs in tokamaks as well as in solar flares, for instance. Transport – especially turbulence – is another issue that is vital for fusion research and which is also studied in astrophysics. A third topic is suprathermal particles, which are crucial for the operation of ITER and future fusion devices, and which also play a substantial role in astrophysics. Lastly, the role of magnetic fields in astrophysical plasmas will be investigated. Besides 21 new postdocs, at least a further 26 scientists, some in senior positions at their institutions, are involved in the centre.

The new Max Planck Princeton Centre is one of a number of International Max Planck Centres, which the Society is currently establishing. To date nine centres have been set up, connecting top class international research partners with Max Planck Institutes in multidisciplinary cooperations. The centres provide the framework for the exchange of scientists, organise common workshops and trainings and promote the common use of research infrastructure.

More information:
http://tinyurl.com/IPP-Princeton
http://tinyurl.com/Max-Planck-Centers
http://www.pppl.gov/

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Fusion plasma on ASDEX Upgrade (Image: IPP)
Background: Stellar plasmas: Three-colour composite mosaic image of the Eagle Nebula (Image: ESO)
A fusion power plant will have to produce all its own tritium. Recently, popular science articles voiced doubts about the feasibility of this idea. However, measurements carried out at the Frascati Neutron Generator in Italy now demonstrate that the concept is valid and enough tritium can be produced.

**TRITIUM AND FUSION POWER**

A fusion power plant burns nuclei of the hydrogen isotopes tritium and deuterium and produces one helium nucleus and one fast neutron. To generate one gigawatt of electricity for one year, the plant consumes more than 55 kilos of tritium. Tritium is practically non-existent in nature and the annual production of nuclear fission reactors worldwide is less than two kilos. Therefore the plant has to breed its own tritium using a reaction between the fusion neutron and the light metal lithium, which generates one tritium and one helium nucleus. The challenge lies in the fact that one burnt tritium yields one neutron, which generates exactly one tritium, so one would have to harvest 100 percent of the fusion neutrons for the breeding. Some neutrons, however, are lost in other wall areas. Moreover, the plant has to produce slightly more tritium than it burns to make up for losses and to keep a small buffer. The solution lies in neutron multipliers. These are elements like beryllium and lead, which react with neutrons and produce a second neutron. The tritium breeding ratio of a fusion plant is the ratio between the amounts of generated and burnt tritium. This ratio must be defined very accurately, as the plant must not build up too much stock of the radioactive tritium (its half life time is 12.3 years). Scientists estimate that a breeding ratio of only very few percent above one is sufficient. The tritium production process takes place in the blankets, which are about one meter large, thick steel elements located at the wall inside the vacuum vessel. Europe is currently investigating two different design concepts for the tritium breeding blankets: One version, called Helium Cooled Pebble Bed, employs helium as a cooling fluid, ceramic lithium pebbles for breeding and beryllium pebbles as neutron multiplier. The other concept, called Helium Cooled Lithium Lead uses a lithium-lead-fluid to breed tritium and multiply neutrons.
A fusion reactor needs to produce all the tritium that it burns, plus a little bit more. For the design of a fusion power plant, this requirement is translated into a tritium production rate inside blankets that surround the burning plasma. The production depends on the neutron flux inside the blanket’s tritium breeding zone. Determining this neutron flux, however, is a complex task: It varies spatially inside the vessel and the neutrons interact with other wall materials before entering the breeding zones. Also, the blankets are designed differently depending on their location inside the vessel, because they have other functions, too. They absorb the energy of the fusion neutrons to heat a cooling fluid, which drives the turbine, and they shield the magnets from the high-energy neutrons. The achievable tritium breeding ratio for a fusion reactor is derived via simulation calculations. A burning plasma generating neutrons is simulated in the vessel (with a number of holes for heating and diagnostic systems) and with divertor and breeding blankets of a certain design. Based on the neutron flux one calculates the tritium production rate in the blankets and then adjusts the design of all components in order to meet the required value, without impairing all their other functions. The calculations need very accurate nuclear data and cross sections of the neutron reactions with all reactor materials. Most of the available data, however, were accurate for neutrons generated in fission reactors, and these carry much less energy than fusion neutrons. The project to develop a high quality nuclear database for fusion began under EFDA and now continues within the R&D program of Fusion for Energy.

Measurements prove concept. The measurements at the Frascati Neutron Generator (FNG) were carried out to validate the simulations and the neutron data used to calculate the tritium breeding ratio in fusion reactor design. Scientists from several European institutions – ENEA, KIT, Technical University of Dresden, Cracow University of Science and Technology and Jožef Stefan Institute of Ljubliana – were involved in these experiments. The experiments were carried out with mock-ups of the two breeding blanket concepts developed in Europe for a demonstration reactor DEMO. Even though in FNG the rate of neutrons per second and per area is much lower than in a fusion power plant, it produces neutrons with similar energy as the fusion reaction, 14 mega electron volts. The neutron energy spectra inside the mock-up breeding zone was the same as it will be in ITER. Over a large number of days the mock-ups were irradiated and the tritium produced measured. The measurements match the simulation calculations within 5.9% error. These results clearly show that the nuclear mechanisms behind the breeding blankets are well understood and therefore also demonstrate that a tritium breeding ratio above one – as predicted by simulations for DEMO – can be realised.

The next step will be to measure tritium breeding in the blanket test modules in ITER, to validate the calculations in a real tokamak environment. While FNG is a point neutron source with well defined conditions, the ITER plasma is a spatially distributed neutron source and creates a harsh environment (high heat and radiation), which also affects the measurement instruments. Therefore new types of detectors, which are expected to withstand these conditions and provide data with the required accuracy, have to be qualified for ITER experiments. These detectors have already been tested at FNG and will be further tested and qualified. Testing could be done also in a deuterium tritium campaign at JET, which is planned for around 2015.

Contact and reference:
Dr Paola Batistoni, ENEA, paola.batistoni@enea.it
P. Batistoni et al, Neutronics experiments for uncertainty assessment of tritium breeding in HCPB and HCLL blanket mock-ups irradiated with 14 MeV neutrons, accepted for publication in Nuclear Fusion (2012)
ELMs  Edge localised modes (ELMs) are events that expel a series of bursts of energy and particles from the plasma. They are akin to solar flares, the spectacular eruptions that occur on the edge of the sun. ELMs happen when the plasma enters a high-performance mode of operation known as H-mode, in which energy is retained inside the plasma much more effectively, but pressure builds up at the edge. As the pressure rises, the plasma tries to release it by letting it escape its magnetic cage. It does so in the form of an ELM – ejecting a jet of hot plasma which can hit the walls of the machine. As the energy released by these events strikes wall surfaces, it causes erosion, which could have a serious impact on the lifetime of plasma-facing materials in ITER.

CCFE’s spherical tokamak MAST is the first device to observe finger-like plasma structures emanating from methods applied to mitigate harmful instabilities. The images could help find a solution to one of the biggest plasma physics problems standing in the way of the development of fusion power.

So called ‘Edge Localised Mode’ or ELM instabilities are powerful plasma events which have the potential to damage components in future machines like ITER. Not surprisingly then, understanding ELMs and developing techniques to deal with them is a high priority in fusion research. The goal of plasma physicists is to stop ELMs from happening at all, but this is easier said than done. For example, reducing the plasma’s pressure can suppress ELMs – but this also impairs its ability to confine energy, one of the key factors for achieving fusion conditions. Another way of tackling the problem is not to eradicate the instabilities but to control them at a manageable level, limiting the amount of harm they can do. This approach, known as ‘ELM mitigation’, is the subject of an intensive campaign of studies worldwide.

Magnetic perturbations. MAST, like many other fusion devices, is using a technique called resonant magnetic perturbation (RMP) to mitigate ELMs. The idea is to apply small magnetic fields around the device to punch holes in the plasma edge and reduce the pressure – and thus the confinement – in a measured way. This technique has been remarkably successful in mitigating ELMs on several tokamaks.

One surprising feature of the RMP method is that as the pressure at the edge of the plasma drops, the number of ELMs increases. With our understanding of ELMs, lower pressure should lead to fewer ELMs, because there is less motivation for the plasma to release energy and particles. Something else must be happening. The clue is in lobe structures that have recently been spotted in images of plasmas inside MAST during RMP experiments.

The lobes are caused by the resonant magnetic perturbation, which throws particles off course as they move around the magnetic field lines in the plasma, effectively changing their route and eventual destination. Some particles end up outside the magnetic field lines, forming small offshoots near the base of the
plasma, at the ‘X-point’. These lobes change the shape of this area of the plasma, which in turn has the effect of lowering the pressure threshold at which ELMs are triggered – causing more frequent but less powerful ELMs. So by shaking up the plasma and deforming a specific part of it, researchers should be able to produce a stream of small, manageable ELMs that will not damage the tokamak – an effective way of keeping them in check.

First images of plasma lobes. First predicted by US researcher Todd Evans in 2004, the lobes – known as homoclinic tangles – were only seen for the first time during experiments at MAST in December 2011, thanks to the machine’s exceptional high-speed cameras. CCFE scientist Andrew Kirk, who leads ELM studies on MAST, says: “This could be a very important discovery for tackling the ELM problem, which is one of the biggest concerns for physicists at ITER. The aim for ITER is still to remove ELMs completely, but it is useful to have back-up strategies which mitigate them instead. The lobes we have identified at MAST point towards a promising way of doing this.”

The lobes are useful for another reason; they are a good indicator of how well the resonant magnetic perturbation is working. The changes in ELM size and frequency tell physicists that puncturing the edge of the plasma with extra magnetic coils is having an effect, but the lobes show how far this effect is penetrating into the plasma. “The length of the lobes is determined by the amount of the magnetic perturbation the plasma is seeing,” explains Andrew Kirk. “So the longer the ‘fingers’, the deeper the penetration. If the fingers are too long, we can see that it has gone too far in and will start to disturb the core, which is what we want to avoid.”

New codes. The next phase of the research will involve developing codes to map how the lobes are formed around the plasma. “We already have codes that can determine the location of the fingers but we cannot, at present, predict their length due to uncertainties in how the plasma reacts to the applied perturbations. Our measurements will allow us to validate which models correctly take this plasma response into account,” says Andrew Kirk. “Our next job will then be to write 3D codes which can calculate the plasma stability in the presence of these lobe structures. This will mean we can produce accurate predictions for ITER and help them tame the ELM.”

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Optical measurements are indispensable for nuclear fusion experiments. The light produced in a plasma speaks volumes about its density and temperature, its composition and the concentration of various isotopes and elements. But ITER and future fusion experiments will burn tritium-deuterium plasmas, whose intense neutron radiation will degrade light-guiding fibres and damage sensitive detectors. Therefore it will only be possible to observe the light indirectly via mirror systems. The mirrors, however, could become contaminated by beryllium and tungsten particles originating from eroded wall materials, which would degrade their reflectivity.

The new concept for ITER involves a system of ducts with mirrors at their ends. This so called mirror station is equipped with shutters which only uncover the mirrors during the main phase of the plasma pulse. These shutters are closed during the ignition of the plasma when the contamination risk is highest. Since the very strong magnetic fields in the vacuum vessel interfere with electrical circuits, the shutters rely on passive control. Once the plasma ignites, it generates a magnetic field which acts on magnetic ferrite cores in the shutters and triggers them to open. Several ducts of the mirror station are trialling special fins to protect the mirrors from incoming particles during the measurements. This would further extend the mirror lifetime.

“We hope that our development will provide a substantial contribution to making optical measurements possible at ITER,” says project head Andrey Litnovsky at Jülich’s Institute of Energy and Climate Research. Testing of the station’s practical applicability began at DIII-D in March. In addition, new mirror stations from Jülich will be installed for experiments in ASDEX Upgrade at IPP, at EAST in Hefei, China and at TEXTOR in Jülich.

Ralph P. Schorn, Forschungszentrum Jülich

More Information: http://www.fz-juelich.de/iek
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EFDA provides the work platform to exploit JET in an efficient and focused way. More than 40 European fusion laboratories collectively contribute to the JET scientific programme and develop the hardware of the machine further. The tokamak is located at the Culham Science Centre near Oxford in the UK. It is funded by EURATOM, by the European Associates, and by UK's fusion Associate, the Culham Centre for Fusion Energy (CCFE) as host. CCFE operates the JET facilities including carrying out the maintenance and refurbishment work required to realise the given scientific goals.
The 20th International Conference on Plasma Surface Interactions, hosted by Forschungszentrum Jülich, was the first occasion to examine in depth the much-awaited results from JET’s new ITER-Like-Wall (ILW). Project leader Guy Matthews from CCFE was the conference’s first speaker and provided an overview of the many encouraging insights gained since operations started in August 2011.

**Smooth plasma formation.** Scientists were surprised how easy it was to generate a plasma with the new metal wall. While the carbon vessel needed several attempts to create the first plasma after a long shutdown, the ILW-machine instantly produced a 15 seconds long plasma pulse with a respectable current of one megampere. Even after disruptions, which are rapid events during which the plasma loses all its energy, the following JET pulse would start without hesitation. This had often not been possible with the carbon wall where a number of pulses could be wasted and so it is good news for ITER, where precious experimental time will be shared among many more scientists than at JET.

**Low fuel loss.** The tendency of carbon to absorb tritium is the main argument for choosing metal walls for the second, tritium-deuterium phase of ITER and for future fusion power plants. Tritium is both valuable and radioactive and must not be allowed to accumulate in the vessel wall for reasons of safety and economics. Comparisons of matched plasma scenarios carried out with the previous JET carbon wall and the ILW show that about ten times less tritium is retained in the ILW. The results so far meet the predictions from studies carried out in advance but we will only know the full story when dedicated wall tiles are removed for analysis later this year.

**Clean plasmas.** Analysis of these wall tiles will also give insights into the erosion of tungsten and beryllium. These materials contaminate the plasma when the vessel wall gets eroded by the heat. Tungsten atoms absorb much more plasma energy than carbon and are therefore a concern. The observed tungsten influxes behave just as expected but fortunately the experiments also show that techniques developed at ASDEX Upgrade can keep the tungsten levels sufficiently low in JET as well.

**Disruptions under control.** With the ILW, disruptions impose much higher heat loads on the wall. The reason lies in the fact that carbon impurities in the plasma strongly radiate its heat away, whereas beryllium radiates much less leaving much more to heat the wall during a disruption. Although the heat loads risk melting the new tiles, a disruption mitigation system based on fast injection of argon and deuterium gas at high pressure has proven an effective way to quench a disruption – rather like a bucket of water on a fire. The JET results are important for ITER, which will need such a system.

**Successful wall protection.** The JET upgrade was quite daring in the sense that it installed a metal wall, which does not resist heat as well as carbon, and at the same time upgraded the plasma heating systems. In other words the new machine is operating with a more sensitive wall in more severe conditions. Therefore considerable effort has gone into designing tiles to maximise their power handling capabilities. Also a wall protection scheme has been devised in which an automated CCD-Camera system surveys the wall temperature and
adjusts the plasma position or even terminates the plasma pulse, if necessary. The system works reliably – so far, the wall is undamaged – and allows the scientists to take the machine closer to its limits so that the plasma conditions can be pushed towards those in ITER.

**ITER scenarios achieved.** Good progress has been made in establishing the plasma scenarios ITER will need with the new JET wall but there have been some surprises and there is more work to do. The power required to obtain the high energy confinement plasmas that ITER needs is lower than expected which is good news. There has however been a need to learn how to access the highest plasma performance whilst keeping the tungsten impurities low in the core of the plasma. Good progress has been made in both the ITER baseline scenario – a high confinement plasma largely relying on induced current – and the so called hybrid scenario which promises longer pulse operation in ITER. One surprise in the inductive scenario is that injecting nitrogen to reduce the power load to the wall can actually increase the plasma performance. This may be good news for ITER which will need to inject impurities to limit the power flow to the wall.

**Encouraging news for ITER.** The first JET results with a beryllium wall and tungsten divertor are very encouraging for ITER. It is also good to see that techniques developed at ASDEX Upgrade with its tungsten wall have turned out to be applicable at JET. This gives confidence that they will also scale up from JET to ITER.

More information:
http://www.efda.org/jet/jet-iter
https://www.congressa.de/PSI2012/
Dr G.F. Mathews et al., *Plasma operation with metallic walls: direct comparisons with the all carbon environment*, proceedings PSI 2012

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New **LIDAR detectors can take the heat at ITER**

JET is home to a Thomson scattering LIDAR system, a unique forerunner for one of ITER’s key diagnostic. Recently, the system was enhanced with modern, highly sensitive and ultra-fast detectors. The measurement results demonstrate that the chosen detector technology delivers highly accurate data and is well suited for ITER.

Thomson scattering (TS) diagnostic systems are one of the most robust and reliable methods of measuring plasma temperature and density in a fusion device. Using intense bursts of laser light, these diagnostics remotely interrogate the thermal motion of the plasma electrons by analysing the scattered light signal. These measurements require powerful laser systems and highly sensitive detectors since the scattering process is very weak (electrons are small!). For every gigawatt of incident optical power, only a few hundred nanowatt return as Thomson scattered light.

**The advantages of LIDAR.** Although TS systems are employed on nearly every large fusion device, JET is the only machine to have a LIDAR variant of this diagnostic. It registers the distance between detector and scattering location by measuring the travelling time of the light signal (time-of-flight), in much the same way that RADAR does with radio-waves. Because it delivers density and temperature information together with the location in just one signal, a LIDAR system is simpler than a conventional TS system. It requires only a single access port into the plasma chamber, whereas the latter needs a second port for a large lens to collect the scattered light separately for each plasma location. For these reasons LIDAR is particularly attractive for ITER, where space is at a premium because of the myriad systems that will surround the vessel.

**Improved resolution.** LIDAR systems rely on short laser pulses and fast detector response times to achieve high spatial resolution – the upgraded system at JET features pulse lengths as low as 300 picoseconds, or one third of one billionth of a second. One of the fundamental challenges for ITER’s LIDAR system is developing and proving fast detector technology featuring high sensitivity for a wide wavelength range, as spectrum of the scattered light is broadened by the Doppler effect. Over the recent shutdown, the TS team at JET has been busy optimising the LIDAR collection optics and replacing the detectors, originally installed in 1986, with ultra-fast and highly sensitive Gallium-Arsenide-Phosphide detectors. These enhancements have led to significant improvements in the signal-to-noise ratio and temperature and density measurements are much more accurate. Scientists can now, for instance, measure at much lower plasma densities. Over JET’s next intervention period the TS team also plan to upgrade the digitising electronics, whose technology is now lagging 30 years behind the new detectors. Making full use of the fast detectors will improve the spatial resolution of the measured profile from 12 cm to the ITER requirement of 7 cm.

These enhancements offer more than just excellent data for JET experiments; the technical knowledge and experience gained throughout this process is invaluable for the ITER LIDAR development; JET is the only place in the world where this measurement technique and its associated technologies can be tested.

*The JET Thomson Scattering team*

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Neutral Beam Injection (NBI) is the principal external heating system on JET. It was upgraded along with the installation of the ITER-Like-Wall in order to increase the flexibility for higher power experiments. Two Neutral Injection Boxes, each delivering eight beams of energetic particles, provide the power to the plasma. Each box was originally designed, over 20 years ago, to provide 7.5 megawatt (MW) for up to ten seconds. Long ago that performance has been exceeded, and the whole system used to routinely deliver over 20 MW. The upgraded design aims for an overall power of 34 MW for 20 seconds.

The NBI heating has been turned up step by step and now, at the end of May, we have about 30 MW available for use, although the full power has not yet been applied to the plasma. The ITER-Like-Wall protection systems are being commissioned systematically as the power levels rise. Without this protection working, there would be a significant risk of over-heating a few plasma-facing components that are particularly exposed, notably the inner wall guard limiters and the divertor.

Long, powerful beams. Meanwhile the system has reached its previous power record of 23.8 MW and routinely supplies more than 20 MW to the plasma. Other records have been achieved almost unnoticed: 14.3 MW was delivered to the JET plasma from just one injection box, beating the previous record of 13.7 MW, and approaching double the value of the original design. A record beam pulse length of 15 seconds, kept up by four of the 16 beams, has also been achieved. Previously the beam pulses lasted at most ten seconds. The long pulse lengths also demonstrate that the water-cooled duct liners work as expected. These were installed to protect the walls of the narrow port through which the beams are injected.

Robust power supply. The Neutral Beam Local Manager software is now commissioned. This controls the 16 individual injection beams and attempts to keep up the pre-set amount of neutral beam power during a plasma pulse, even if one beam happens to fail. It thus makes the experiments more robust. With this system in place, scientists control the delivered power in real time for the first time since operations restarted. This factor, along with the availability of a substantial amount of heating, has opened up the opportunity for some interesting experiments. The sense of excitement in the JET Control Room suggests that good results are being achieved.

Nick Balshaw, CCFE

More information: http://www.efda.org/category/jet-in-close-up/
Some of the nearly 960 persons who paid a visit to JET from March through May:

- 262 school students, along with 46 teachers, visited the facilities.
- About 106 university students and scientists from various disciplines visited JET/CCFE.
- 151 industry representatives came for tours, events and discussions.

Ten Delegates from the **Chinese Ministry of Science and Technology (MOST)** and delegates from the **European Commission** held their executive meeting under the R&D PUNE Agreement at JET on April 12. PUNE is a bilateral Agreement between China and the European Union for R&D cooperation in the peaceful uses of nuclear energy. The meeting at JET was the first one about fusion energy research. China invests heavily in fusion research and operates the Experimental Advanced Superconducting Tokamak EAST. It is also planning to construct another fusion experiment. The Chinese delegates took the opportunity to tour the JET site and expressed a lot of interest in technologies developed at JET, such as the remote handling facilities.

**Dr Stefan Kaufmann**, member of the German Parliament, visited JET on April 11. Dr Kaufmann belongs to the conservative Christian Democratic Union (CDU) and has already visited German fusion experiments. He came to Culham to experience Europe’s largest tokamak JET and to meet EFDA Leader Dr Francesco Romanelli. “We do have an increasing discussion in Germany about ITER and it is important for me to see how such a large tokamak, which investigates central issues for the realisation of ITER, really works,” he explained. Kaufmann was impressed by the international nature of research at JET: „It is striking to see how the experiment is managed and supported not by one nation alone, but that scientists from all member states and from EFDA operate and advance JET collectively. I find that really notable, especially since ITER will have to work in a similar way.“
The tokamak experiment near you

With its remotely operated tokamak Golem Czech Technical University in Prague makes experimental fusion possible for students that do not have direct access to a fusion machine.

“For many, fusion is far, far away”

Czech scientist Milan Ripa once said to underline that the only fusion machines in entire eastern Europe are located in Prague. Worldwide, around 50 tokamak experiments are up and running and not all students fascinated by fusion energy happen to live near one. But now they can enrol in the GOMTRAIC project and – within an international team of fellow students and under the guidance of a scientist – operate a tokamak from home.

GOMTRAIC stands for GOlem reMote TRAIning Course and is offered by the Faculty of Nuclear Sciences and Physical Engineering, at the Czech Technical University in Prague. The faculty’s small tokamak Golem can be fully operated remotely via the internet. It has been used for many face-to-face experimental fusion summer schools over the past years, and now the faculty is using this experience to pioneer a remote training course. GOMTRAIC aims at Masters and PhD students with an interest in experimental tokamak physics. All they need is a recommendation from their tutor and internet access. Within three months, they learn how to conduct tokamak experiments and how to operate the diagnostic systems that measure the plasma.

Global participation. The first course started in March 2012 and was advertised through personal contacts and through FUSENET, a European fusion education network. Almost fifty participants registered from all over the world. They were split into nine groups and each student was assigned to one task according to his or her preference and was guided by an experienced supervisor. A remote kick-off meeting introduced the participants to technical aspects of the measurements. An internet-based GOLEM simulator programme helped them learn about the operation of the machine. Although the group never met in person, they communicated via email and videoconference to jointly design the experiments. They met in the virtual control room to perform the plasma measurements, evaluate the data and present a report on their experimental results. The performed discharges were displayed on the website from where the students could download their experimental data.

Just the beginning. GOMTRAIC is the first experimental fusion summer school with purely remote participation. This time it brought together students from 16 countries in Europe, Asia and America. The GOLEM tokamak is simple enough to be manageable for projects of this scale, so students can get an excellent insight into the basic principles of fusion machines. The next course is planned for 2013.

Contact and information: http://tinyurl.com/gomtraicTraining
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GOLEM with its plasma that can also be created from afar. The Czech Technical University uses the tokamak for remote experimental training. (Picture: Bara Drtinova, Czech Technical University)
EFDA and ITER had a strong presence at the Second European Energy Conference in April, with both the EFDA leader, Francesco Romanelli and the Director General of ITER, Osamu Motojima delivering plenary lectures. There were also papers presented by EFDA Associates on materials for fusion reactors and about modelling far-reaching energy scenarios to investigate fusion's place in the future energy market.

There is no silver bullet. The conference brought together policymakers and specialists from many different fields, who shared the progress in their areas, with the aim to “optimise the necessary interdisciplinary cooperation and communication in energy research, development and the support to industrial innovation”. Over 300 participants heard lectures from research topics as diverse as primary energy production and supply networks to US energy policy and efficient end-use of energy. The shared feeling amongst the participants was that there is not a silver bullet which will solve the looming energy crisis, instead many different technologies will contribute to the solution.

Fusion strongly present. Both EFDA and ITER had stands in the conference expo, which attracted a steady stream of interested visitors. The EFDA stand included a remote handling hands-on demonstration, a recent addition to EFDA’s travelling exhibition, Fusion Expo. This exhibit simulates the operation of a robotic arm similar to the one used to conduct maintenance at JET. Visitors were challenged to manipulate “tiles” – wooden blocks – into their allotted spaces using only the on-screen camera view. However, the two minute time limit for the four tiles proved too testing for all but one contestant, giving visitors an appreciation of the skill that the JET technicians showed: During the 2009 – 2011 shutdown, they replaced 86,000 components inside the JET vessel using remote handling techniques.

The conference was presented by the European Science Foundation, the European Materials Research Society and the European Physical Society, and took place in Maastricht, from April 17 to 20, 2012.

Phil Dooley, EFDA

More information:
http://www.energy-conference.eu
Max Planck Gesellschaft opens energy exhibition

The exhibition pinpoints ways out of the impending energy crisis and highlights alternatives to present-day energy production. Photos, films and interviews provide fascinating insights into fundamental research fields that range from investigating and modelling climate change via computing to sketching global energy scenarios. Exhibits on research for energy production cover fields like nuclear fusion, fuels produced from solar energy or artificial photosynthesis. Max Planck Institute for Plasma Physics is one major contributor to the exhibition and provides deep insights into fusion research. The institute also exhibits global energy system models that investigate possible future pathways towards a sustainable energy supply. The models deliver scenarios which support decision makers to set the course of the future, embracing a wide spectrum of technological, economic and political options.

„SONNENWENDE“
– the German word for solstice is composed of the two words „solar“ and „turnaround“. Max Planck Gesellschaft (MPG) used the word’s ambiguous nature and named its energy exhibition „Sonnenwende – sustainable energy for the future“. IPP Director Professor Sybille Günter and Professor Robert Schlögl, Director of the MPG’s Fritz-Haber-Institut, are mentors of the show which started on June 12 in Berlin and will be open until autumn this year.
Exhibition on demand for stakeholders

Max Planck Science Gallery was inaugurated in September 2011. The exhibition uses state of the art digital communication formats and changes topic every few months. It is deliberately located in Germany’s capital Berlin and aims at politicians or other stakeholders, who can use the gallery as a showcase for German research. Set up fully digital, the exhibition can display any pre produced show within minutes and therefore cater for various interest groups. Since it opened, the gallery has received on average between 70 and 100 visitors per day.

More information: http://www.max-planck-science-gallery.de/

Video: Modern cello music on ASDEX Upgrade
Cello Virtuoso Johannes Moser performed the world premiere of his piece “Magnetar” on ASDEX Upgrade.

Pictures in print quality
High resolution image request now available via a comfortable and quick ticketing system.

Straight from the control room: JET in close-up
Nick Balshaw, one of JET’s engineers in charge regularly reports on the machine.

Video: A snowball’s chance in Hell
Frozen pellets of gas are being fired into the JET plasma.
Karlsruhe International School on Fusion Technologies

Karlsruhe, Germany, 3–14 September 2012

Deadline for application: 31 July 2012.

The course addresses university and technical high school students. Financial support through European Commission funds can be granted for a limited number of participants.

More information:
http://summerschool.fusion.kit.edu

Dutch Institute for Fundamental Energy Research

Dutch Associate broadens research mission

On 16 April, DIFFER, the Dutch Institute for Fundamental Energy Research opened in Nieuwegein, The Netherlands. The Institute was previously known as FOM Institute for Plasma Physics Rijnhuizen. In 2011, its funding agencies FOM and NWO decided to broaden the Institute's mission to fundamental energy research.

Under the motto Science for Future Energy, DIFFER aims to become a leading institute for fundamental energy research. It will continue its strong fusion-related research, and will also start a separate research line into solar fuels. These chemical fuels are produced via artificial synthesis and serve as energy storage for fluctuating renewable energy. To facilitate a closer cooperation with academic researchers in these fields, DIFFER will move to a new laboratory building at the campus of Eindhoven University of Technology in 2015.

More information: http://www.differ.nl/en

Where is Fusion Expo?

12 May – 8 July 2012
Visiatome Marcoule, France
http://www.efda.org/fusion-expo
Contact: Tomaz Skobe, tomaz.skobe@ijs.si

A travelling exhibition financed by EFDA.
28 European countries signed an agreement to work on an energy source for the future:

EFDA provides the framework, JET, the Joint European Torus, is the shared experiment, fusion energy is the goal.